METALLURGIA

THE BRITISH JOURNAL OF METALS

INCORPORATING THE "METALLURGICAL ENGINEER."

SEPTEMBER, 1951 Vol. XLIV No. 263

"The Mixture as Before"

PERHAPS we shouldn't be surprised at the similarity in the general conclusions arrived at by the various specialist teams which have visited the United States to see what American methods and equipment might usefully be adopted in this country. After all, the American worker has the same attitude towards work whether he is a welder or a foundryman. Most of the teams have experienced some difficulty in defining productivity with sufficient precision to be able to measure it quantitatively. One may, therefore, question the actual ratio of American to British productivity quoted in some of these reports, but the painstaking way in which the teams have gone about their task—and this is seen very clearly from a study of the reports in which an attempt has been made to see all aspects of the various matters discussed—leaves no room for doubt that in all cases the American figure is higher than ours. No exception to this statement is to be found in the two reports published this month on Welding and Hot Dip Galvanizing,* although the Welding Team does suggest that there may not be much in it. It hastens to add that that should not detract in any way from the urgency of applying at home those features of the American welding industry which, if applied, would certainly improve our productivity.

It is pleasing to note in these reports that the Americans are not ahead technically in either field. The Galvanizing Team soon found that the greatest lessons were to be learnt in the matter of work handling, and that the fact that the technical processes were simpler and less efficient than modern British practice was considered by the Americans to be of secondary importance compared with the means to secure the maximum output. The main distinction between American and British galvanizing technique is the almost exclusive use of hot sulphuric acid for pickling in the U.S. Although it has technical advantages, and is, on the basis of acid equivalent, cheaper than hydrochloric acid, the latter is preferred in Britain because it does not need heating.

In the welding field, the only outstanding superiority noted in plant of general application was the recently introduced "Aircomatic" torch, in which a consumable electrode is shielded by argon or helium, a development which shows great promise of increasing the range and reducing the cost of welding non-ferrous metals. Generally speaking, American welding electrodes are not superior to the British, although an exception must be made of a low hydrogen electrode for use with a chrome-molybdenum steel for steam pipes. On the resistance welding side, there appears to be a greater use in the U.S. of machines having a three-phase supply and of multiple electrode spot welding machines.

As in previous reports, attention is drawn to the emphasis placed on the planning and routing of work and materials to avoid waste of time, and to the greater use made of mechanical aids to assist or eliminate manpower, particularly in all aspects of handling. In welding, for instance, the time of laying down a particular run of weld metal is mainly governed by the electrode and the current, and no amount of effort on the part of the operator can accelerate it. It will readily be appreciated, therefore, that the welder's output is directly related to the percentage of his time spent in welding, a figure which can be greatly increased by the use of suitable manipulators and other handling equipment. A point which has been noted in several reports is the widespread use of "local" lifting equipment to obviate waiting for the shop crane, and the Galvanizing Team observed that all the shops visited were very well equipped with electric monorail hoists, running on straight lines, loops or elaborate tracks with several switch points, and recommended that "the maximum use should be made of travelling hoists of relatively light capacity (5–10 cwt.) to eliminate heavy manual work."

When all the technical improvements have been effected, however, there still remains to be considered probably the most important factor influencing productivity—namely, the human element. As Lady Violet Bonham-Carter said recently—"It is not unemployment but under-production which threatens our standard of life. It is extraordinary," she continued, "that in this year of grace we should still have Luddites who strike against a machine instead of using it to raise their own living standards and that of the nation." In marked contrast, the American working man is not in the least apprehensive of mechanisation, because he sees more clearly in his mind the direct relationship between greater productivity and a higher standard of living. He is proud of the fact that the American standard of living is already higher than that of any other country, and his anxiety that it should not fall back but constantly advance spurs him on to even greater effort.

An interesting comment is made by the Galvanizing Team on the extent to which teamwork, in a modern highly organised industry, has taken the place of personal craftsmanship as a means of satisfaction in work, since the idea of teamwork appeals to something inherent in human nature. Although in many plants there were incentive schemes, the introduction of which was said in some cases to have increased production to a noticeable extent, they were not in use in all establishments; but even where there were no such schemes, the men seemed to work together effectively as a team. Every encouragement was given by the quality of the supervision—a factor which has been noted in earlier reports—which is directed towards the arranging of the work in such a way that every man is naturally kept fully employed, thus giving full scope to the will to work which is particularly evident in America.

* Copies of these Reports may be obtained from the Anglo-American Council on Productivity, 21, Tothill Street, London, S.W.1. Price, 3s. 6d. each (post free).

Swedish Steel Industry Expansion

THE Swedish iron and steel industry is engaged in carrying through an extensive programme of expansion and modernization, which is estimated by 1955 to raise the productive capacity to well over 2,000,000 tons of ingot steel per annum as compared with the present annual output of 1,400,000 tons, writes "Index," quarterly of Svenska Handelsbanken, Stockholm.

An output of 2,000,000 tons of ingot is equivalent to about 1,400,000 tons of iron and steel ready for the market, a quantity equal to Sweden's present consumption. Most of the planned increase in production is concerned with iron products of the kind represented in the traditional imports. It is expected that, thanks to the increase in production, it will be possible to reduce the requirements of imported iron and steel to about 200,000 tons per annum, which is approximately one-third of the present figure. At the same time it is hoped that exports can be increased from the present volume of about 120,000 tons a year to a similar quantity of 200,000 tons. Seeing that Swedish iron imports consist almost exclusively of cheap iron products, whereas exports comprise mainly high-grade steel with a many times higher value per unit of weight than the imported iron, Sweden's foreign trade in iron and steel products may be expected to yield a considerable net surplus.

The bulk of the planned rise in productive capacity will be accounted for by the State-owned Norrbottens Järnverks AB at Luleå, in the North, with an increase of about 250,000 tons, and the private plants Domnarfvets Jernverk AB with 200,000 tons and Fagersta Bruks AB with 60,000 tons. Smaller increases in output are being planned by nearly all the other steel works.

The large-scale expansion of Norrbottens Järnverk decided upon by the Riksdag in 1946 has involved an outlay of about 260,000,000 kronor (£17,900,000). When the programme of expansion is completed—according to the estimates not earlier than at the end of 1952—the productive capacity of the works will amount to about 500,000 tons of pig iron per annum, which is nearly two-thirds of Sweden's present total production of that article.

Risk of Over Production Very Small

In some quarters warnings have been uttered against the possibility of a dangerous surplus of steel production in Europe in two or three years' time. According to an estimate foreshadowing the production and requirements of steel in Europe, worked out by the Steel Committee of E.C.E., Europe's production of steel (excluding that of the Soviet Union) will increase from the present total of 61,000,000 tons to nearly 75,000,000 tons in 1953. At the same time, Europe's requirements are estimated to rise from 58,000,000 tons to 60,000,000 tons and the Continent's export possibilities from 4,000,000 to 6,000,000 tons. The result would thus be a surplus production of about 9,000,000 tons. This forecast, however, takes no account of the rearmament now going on.

If we attempt to gauge the world's steel requirements at longer range, it looks as if there should be room for a very substantial increase in consumption, the report states. The present world production of ingot steel amounts to about 190,000,000 tons a year, representing about 80 kilogrammes per head of the population. However, in very large parts of the world actual consumption is far below this average. Consequently the progressive industrialisation of under-developed territories may be expected to entail a very large increase in the demand for steel products. Europe's own normal steel requirements will also, it may be presumed, show a fairly considerable rise. With one or two exceptions, steel consumption per inhabitant in the countries of Europe is at present short of 200 kilogrammes, in some cases below 100 kilogrammes, while the corresponding figure for the United States is over 500 kilogrammes.

Sweden's annual consumption of iron, which at the turn of the century was just over 50 kilogrammes per inhabitant, is now up at about 200 kilogrammes. It has been estimated that up to the year 1963 the consumption will rise to around 260 kilogrammes, making an approximate total of 2,000,000 tons a year. The expansion of the Swedish iron and steel industry's capacity, both planned and under construction, is thus no greater than the anticipated rise in the country's own consumption.

When gauging the future prospects of the Swedish steel industry, account should also be taken of the fact that the extension and modernization of plants now going on will enable the steelworks to operate more efficiently and thus to produce more cheaply, and this is bound, of course, to strengthen the industry's competitive power on the international market. Nor should it be overlooked that the steelworks have undergone considerable financial consolidation since the crises in the 1920's and 1930's. There is, therefore, reason to suppose that the Swedish steel industry, which has already survived a number of very serious crises, will be capable of successfully facing any difficulties that may arise in future.

Beilby Memorial Awards

FROM the interest derived from the invested capital of the Sir George Beilby Memorial Fund, at intervals to be determined by the Administrators representing the Royal Institute of Chemistry, the Society of Chemical Industry and the Institute of Metals, awards are made to British investigators in science to mark appreciation of records of distinguished work. Preference is given to investigations relating to the special interests of Sir George Beilby, including problems connected with fuel economy, chemical engineering and metallurgy, and awards are made, not on the result of any competition, but in recognition of continuous work of exceptional merit, bearing evidence of distinct advancement in science and practice.

In general, awards are not applicable to workers of established repute, but are granted as an encouragement to younger men who have done original independent work of exceptional merit over a period of years.

The Administrators are empowered to make more than one award in a given year if work of sufficient merit by several candidates is brought to their notice. In 1950 two awards, each of one hundred guineas, were made to Mr. W. A. Baker and Dr. G. Whittingham.

Consideration will be given to the making of an award or awards from the Fund early in 1952 and the Administrators will therefore be glad to have their attention drawn to outstanding work of the nature indicated, not later than December 31st, 1951.

All communications on this subject should be addressed to the Convener of the Administrators, Sir George Beilby Memorial Fund, Royal Institute of Chemistry, 30, Russell Square, London, W.C.1.

Ultrasonic Soldering of Light Metals

By A. E. Crawford* A.R.Ae.S.

The refractory nature of the oxide film present on the surface of aluminium and its alloys calls for the use of very active fluxes in soft soldering by normal methods, and this, in turn, gives rise to corrosion difficulties. A recent development in this field is the use of ultrasonics for the purpose of erosion of the oxide film. The advantages and limitations of the method are discussed, and details are given of equipment available for its application.

THE difficulty of soft soldering metals possessing refractory oxides has for long been an obstacle to the easier utilisation of such metals for small fabrications. Welding and riveting can, of course, be used but, with the former, distortion of light assemblies due to the high temperatures is a great disadvantage, and the latter usually requires the cleaning up of unsightly rivet heads. Neither method is easily adaptable for mass or automatic production and both require skilled operatives.

Recently, the use of plastic cements for jointing has been introduced. Joints of sufficient strength for many purposes can be produced, and the aircraft industry is using this method in the production of light metal assemblies. There are obvious disadvantages to such a jointing medium : the resistance of the jointing medium to many solvents is low ; it is difficult to get a satisfactory electrical bond ; and great care must be taken in the manufacture of the joint. The curing of the jointing medium by baking is required and this means elaborate mass production procedures. The production of food containers by this method has been established and pressed cans with cemented covers producing vacuum tight joints can be obtained.

It has been found that nearly all light metals can be wetted with the normal range of soft solders when the oxide layer is removed, and the production of joints between the tinned surfaces is then a practical possibility. As is well known, the use of a fluxing agent in the soldering of the usual metals performs two main functions—the removal and inhibition of the oxides, and the improvement of surface wetting of the parent metal by the solder. With normal metals such as copper and iron, this can be carried out with weak acid, alkaline, or resin fluxes and presents no great difficulty. The fluxes are usually not very active and can be washed off afterwards if there is a possibility of corrosion. In most cases, the chemical reaction between the oxide and the flux is of much greater activity than that occurring between the flux and the base metal.

With aluminium and similar light metals the oxide layer is extremely tenacious and chemically inert, resisting all but the most virulent type of flux such as phosphoric acid. The use of such fluxes, however, possesses many disadvantages. In most cases there is a reaction between the base metal and the flux before any reaction occurs between it and the oxide and, since it is usually very difficult completely to clean the surface of flux during or after jointing has been effected, there is always a possibility that corrosion will occur at a later stage with a subsequent deterioration of the joint strength.

Many fabricated structures now incorporate light alloys for panelling, and a number of automobile manufacturers employ such metals for body building. It will be realised that successful soft soldering in such industries is of great importance. The filling of welded seams before painting and the repair of dents or production of moulded contours is generally carried out by the use of soft solders. The use of phosphoric acid as a fluxing medium has been employed for this purpose and the procedure is quite complicated if consistent results are to be obtained.[1]

A second method employed for oxide removal and at times used in conjunction with phosphoric acid washes, is to abrade the oxide from the metal surface by mechanical means. A fine wire brush is employed for this purpose and is used by brushing the metal surface below a pool of molten solder. Oxide particles are removed from the surface by the scratching action and as the molten solder will prevent re-oxidation, tinning will result.

Ultrasonic Erosion

It has been known for some time that the application of intense ultrasonic vibrations to metallic surfaces will produce an erosion of the surface. German reports as early as 1936 give details of the application of ultrasonics to the tinning of light metals, and since then a number of papers have been published covering ultrasonic equipment designed specifically for this purpose.[2-4] It was subsequently found that the effect of ultrasonics was to produce cavitation, or the implosion of small gaseous pockets within the molten solder.[5] The implosion pressures produce a disrupting effect on the oxide and similar results are obtained to those with the use of a wire brush but with an infinitely better surface coverage.

Recent research work has shown that cavitation intensities increase at the lower frequency end of the ultrasonic spectrum.[6] As the frequency is increased, the sudden collapse of the cavitation bubble is changed into a more gradual oscillation. The production of cavitation under normal conditions is also dependent on the energy intensity of the ultrasonic wave and the choice of a suitable transducer for producing ultrasonic energy will depend on these two factors.

The choice of frequency is also governed by the nuisance value of the ultrasonic sound wave. It has been found that 20,000 cycles per second is sufficiently high to be inaudible to most human beings and at the same time will readily induce cavitation. The generation of intense ultrasonic power in this range is most conveniently carried out by magnetostriction transducers and they enable robust assemblies to be built, suitable for most industrial applications.

The magnetostriction effect is a change in the physical dimensions of a material when it is subjected to a magnetic field, and is experienced in many ferro-magnetic materials. The change in length per unit length varies

* Mullard, Ltd.

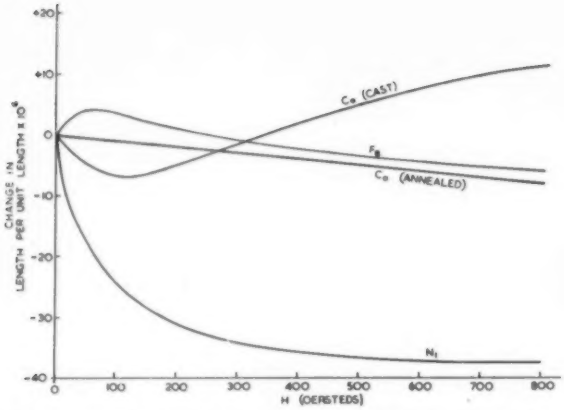

Fig. 1.—Magnetostriction effect in iron, nickel and cobalt.

with different metals and alloys. Nickel, for example, shows a maximum change of about 30 parts per million and transducers composed of nickel or cobalt alloys are generally used for the production of ultrasonic vibrations in the range 15 Kc/s. to 100 Kc/s. It should also be noted that the polarity of change also varies with different materials and magnetic field intensities. Fig. 1 shows changes of length per unit length in iron, nickel and cobalt and it will be seen that iron expands in relatively low magnetic fields and contracts at high field intensities. The polarity of the change is not affected by the polarity of the magnetic field, and in normal electromagnetic systems it is necessary to provide an initial polarising field by means of a D.C. current through the exciter coil or by means of a permanent magnet.

Ultrasonic Soldering Iron

The Mullard* ultrasonic soldering iron utilises a magnetostriction element excited longitudinally, and the transducer is operated at a half wavelength resonance. This will mean that there is a node of vibration at the physical centre and an antinode at either end. Neglecting end corrections, the fundamental frequency can be given by

$$f_0 = \tfrac{1}{2}\, l\sqrt{E/P}$$

where E = Young's Modulus in dynes/sq. cm., l = length in cm. and P = density in g./cu. cm.

* Mullard soldering irons and baths, and certain applications of ultrasonics to tinning are covered by pending British Patent applications.

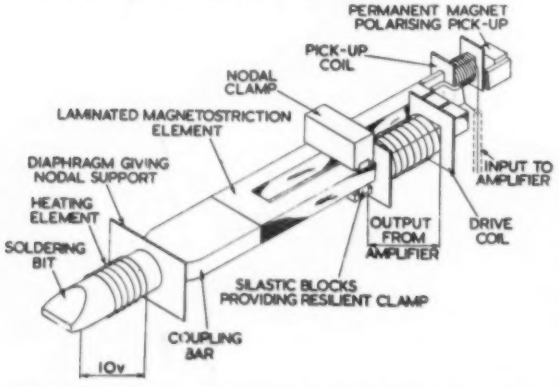

Fig. 2.—Basic construction of soldering iron unit.

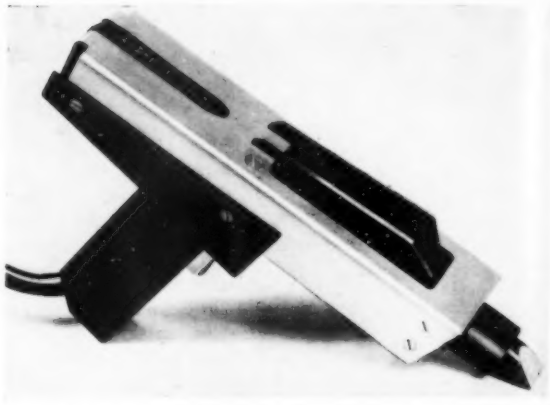

Fig. 3.—Ultrasonic soldering iron. Hand unit.

Such a resonator can easily be mounted at the centre node, allowing free vibration at its ends. A number of Continental versions of ultrasonic soldering irons utilised thin walled nickel tubes as a transducer, but it has been found that the overall efficiency is poor in such systems, mainly due to the large eddy current losses experienced. Slotting the tube has been tried to reduce these losses, but this mechanically weakens the structure and also induces deterioration at the edges of the slots due to physical failure of the metal. The Mullard transducer consists of a pack of cobalt alloy laminations insulated from each other in transformer style. The soldering iron bit is connected to one end by means of a half-wavelength metal bar of similar cross section to the transducer. These components are hard soldered together at the faces and an interface flow of hard solder has been found essential for maximum efficiency. The bit is held mechanically rigid by a metal diaphragm allowing longitudinal movement. Excitation of the transducer is produced by a high-impedance coil wound on one limb of the transducer, the magnetic circuit of the U-shaped element being completed by a magnetic alloy block.

In earlier models, the driving of the transducer was carried out by means of a local oscillator and a power amplifier. A choke and condenser network enabled the same coil to be used for both excitation and initial polarisation. This method has many drawbacks, the most important being that the resonant frequency of any magnetostrictive system varies with temperature.

It will be seen that the ultrasonic output from a transducer will reach a maximum efficiency when the system is operated at its natural resonant frequency. This means that the local oscillator will require continuous re-adjustment when the natural frequency of the transducer varies with its external influences of temperature and loading.

A system was, therefore, developed making the unit self-oscillatory. This was done by introducing a small variable-reluctance pick-up with permanent-magnet polarisation at the rear end of the transducer ; movement of the transducer sets up a corresponding voltage in the pick-up coil, which is fed to the amplifier whose output supplies the driver coil. Frequency-limiting circuits ensure that the system vibrates only in its main nodes. The power amplifier is of a conventional class C type and employs parallel-operated output pentode valves feeding directly into the high-impedance driver coil.

The reactive component of the transducer loop is tuned out by means of a coupling condenser. The driver coil also carries the D.C. polarising current supplied by low voltage rectifiers and the main amplifier feeds approximately 55 watts at ultrasonic frequency to the transducer.

The general arrangement of the Mullard ultrasonic soldering iron is shown in Figs. 2, 3 and 4. The magnetostriction element is contained in a lightweight pistol grip assembly. The nickel-silver soldering bit is electrically heated by a low-voltage resistance winding and the ultrasonic power is controlled by means of a trigger switch. A multicore cable connects this unit to the power supply. Cooling fins are fitted to the transducer assembly in order to prevent overheating by the heat conducted back from the bit.

A modification of the same driving system is used in the construction of a tinning bath, Fig. 5. The soldering bit has been replaced by an electrically-heated bath containing molten solder. The transducer propagates an

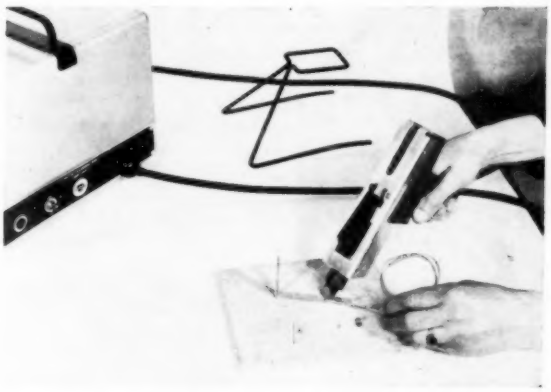

Fig. 4.—Mullard ultrasonic soldering iron in use.

intense ultrasonic wave through the solder, thereby inducing cavitation, and articles to be tinned are dipped into the bath.

Transducers have also been developed with greatly increased surface areas. These are driven by larger generators and can be incorporated into existing solder baths without elaborate modifications. Fig. 6 shows a transducer of this type. It is necessary to bring the work into close proximity with the active face of the unit as the cavitation effect falls off rapidly with increasing distance. When large areas require to be tinned it is sometimes possible to arrange for the work to be passed in front of the transducer face through a trough of solder. Alternatively the work can be placed in a solder bath and the transducer moved over the required area. Finally, it is possible for a multiplicity of units to be arranged in a bath over the required area and the complete bank driven by a large generator. Ultrasonic generators with outputs up to 25 kW. are in construction and this means that large surface areas can be tinned without movement of transducers or work.

Soft Solders

As previously stated, most normal soft solders will wet aluminium and its alloys. There would appear to be a slight alloying between the base metal and the solder, on which is eventually floated a surface of pure solder,

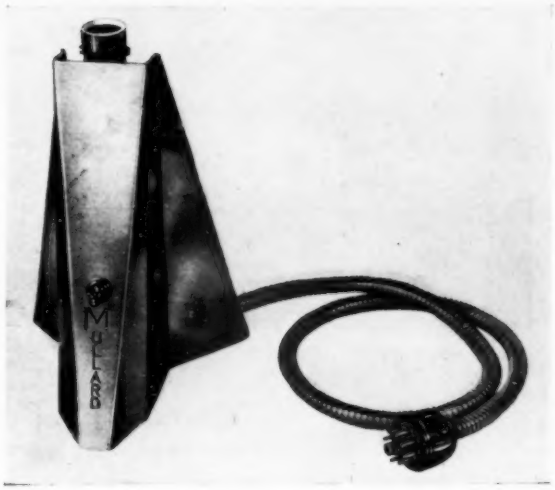

Fig. 5.—Mullard ultrasonic soldering bath.

Oxide removed from the surface of the metal floats on the molten solder and can be wiped clean. This cleaning of the surface is essential if dry joints are to be avoided and once a clean tinned surface has been obtained, jointing can be effected by normal means. Fig. 7 shows an etched lap joint in aluminium, and it will be noted that complete wetting has been obtained. This is signified by the meniscus shape of the deposited solder at the fillets.

When considering aluminium as a substitute for fabricated parts usually composed of normally solderable metals, certain limitations should be borne in mind. The most important factor is that when using the iron, tinning will only occur in the immediate region of contact. Normal soldering methods employing capillary flow to obtain coverage cannot be used, and in the case of irregular surfaces, the alternative is to dip-tin initially in an ultrasonic solder bath and then employ a resin flux and additional solder in subsequent operations. The second factor is the resistance of the joint to corrosion. Most soft solders possess electrode potentials differing widely from those of the light metals and, in the presence of moisture, electrolytic action can cause rapid corrosion

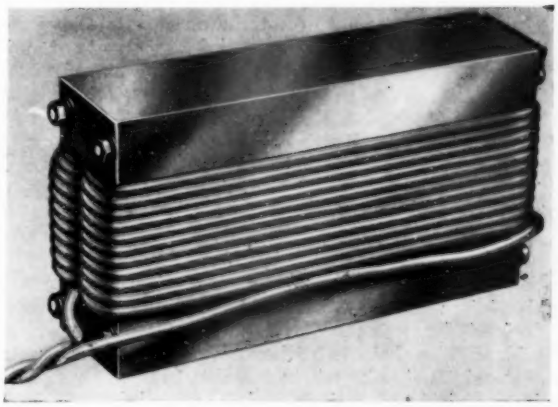

Fig. 6.—Magnetostriction transducer.

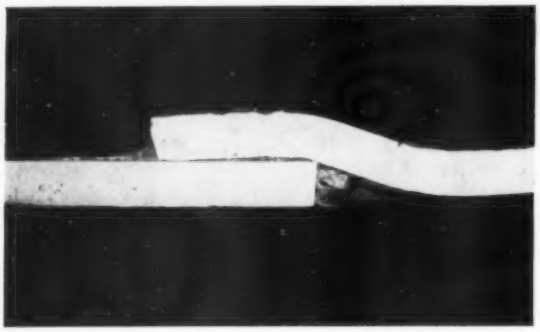

Fig. 7.—Lap joint in aluminium using tin-zinc solder. Etched. ×4

of the solder or the base metal. Table I gives a list of potentials of metals and alloys immersed in sea water at 25° C. and referred against a calomel electrode. It is generally recommended that a potential difference of not more than 0·25 volts is experienced between dissimilar metals in joints exposed to outdoor conditions. A large measure of protection can be achieved, however, by painting or protecting the surfaces from moisture.

A third factor should be considered if the soldered articles are to be subjected to mechanical stresses. With aluminium and many of its alloys intergranular penetration occurs when tin-bearing solders are applied to stressed surfaces. In most cases this need not be serious unless thin panels are being tinned after stressing has taken place. For example, the tinning of a car body panel preparatory to the building up of the surface may result in cracks appearing along the lines of stress.

The two latter factors can be almost entirely eliminated by the correct choice of solder and the alloy or grade of aluminium to be used. A tin/zinc solder has been used for some time in conjunction with mechanical aids to soldering, and it would appear to be satisfactory from the above points of view. However, owing to its considerable temperature range in the pasty state it is not easy to obtain clean joints. The inability of this solder to flow freely is also a disadvantage when surfaces are required to be covered evenly without necessitating further wiping.

Applications

In the fabrication of many articles there are great advantages in the use of aluminium and its alloys. Its light weight, ease of working and durability are of major importance and the introduction of equipment for satisfactory soft soldering will go far to increase the application of such metals. Electrically, it can be employed in many ways. Although possessing a higher specific resistance than copper and thus requiring greater volume for equivalent characteristics, there is a saving of 30% in weight and 30% in cost. This is of major importance in the aircraft industry where electrical equipment is rapidly becoming a considerable weight factor. With the existing world shortage of copper, replacement by aluminium will fulfil many other demands, such as motor field windings, transmission cables and heavy current cables. The obstacle in the past to wider employment of aluminium has been in its inability to be easily soldered for electrical connections, and the unsatisfactory results obtained when clamped joints are made, mainly due to the plastic characteristics of the metal under pressure.

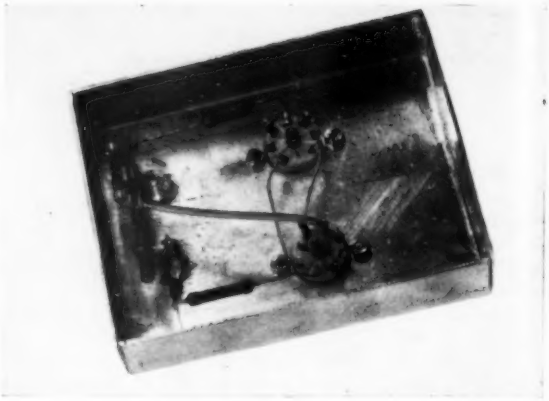

Fig. 8.—Aluminium chassis assembly with earthing and anchor tags soft soldered in position.

TABLE I

Material	Potential (with reference to Calomel Electrode)
Aluminium	− 0·75
Aluminium Bronze	− 0·23
Brass	− 0·30
Copper	− 0·18
Duralumin	− 0·69
Magnesium Alloys	− 1·58
Phosphor Bronze	− 0·22
Tinman's Solder	− 0·48
Tin/Zinc Alloy 80/20	− 0·99
Zinc/Cadmium Solder	− 1·04

In most cases, it is desirable to pre-tin the aluminium in order that conventional soldering irons can be employed during production. Where multi-stranded cable is used, pre-tinning of the individual strands can be arranged as a continuous process by employing a solder bath. The manufactured cable can then be cut at any point and soldered to connections by a normal soldering iron and solder. Many other mass-production processes can employ the soldering bath in conjunction with standard line production methods, and the use of immersible transducers enables existing solder baths to be employed without major alterations.

Tubular condensers of aluminium foil construction have in the past used a pressure joint between the end of the foil and the external connector. This system is satisfactory for many applications, but for stringent mechanical conditions there is a tendency for poor electrical connections to develop. Using an ultrasonic soldering iron or bath, the end of the coiled foil can be completely tinned, thus enabling a positive connection to be made. This can be carried out on a production basis by means of a travelling conveyor, and high production speeds achieved.

Chassis for electronic assemblies are often manufactured in aluminium when prototype or experimental units are required. In most cases, the chassis material is used as a common or earth return and connections are made by riveted or screwed connector tags. This type of connection is not satisfactory over a period of time, due to the cold flow effect occurring under pressure in most light alloys. The deterioration of the joint becomes electrically apparent by the variation in resistance. This disadvantage is very important when high-frequency circuits are used, as the surface conduction or "skin

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Fifty Years of the N.P.L.*

Some Aspects of its Work Reviewed

By V. S. Swaminatham

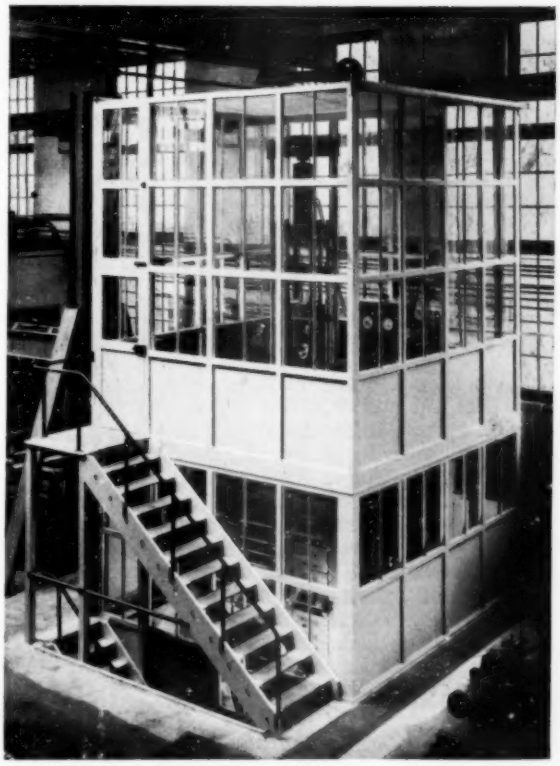
The National Physical Laboratory has now been in existence for 50 years, and in that time has contributed greatly to the advancement of the physical sciences. In this article, the author reviews some of the achievements of the N.P.L. in our field and makes reference to work at present in progress, dealing in this issue with the Engineering, Electricity and Metrology Divisions of the Laboratory.

The Engineering Division

The first of the various branches of the work of the N.P.L. to be constituted a separate Division was Engineering which, under Dr. D. G. Sopwith, is occupied with research on engineering materials and design on a very broad basis and the development and application of the principles of fluid dynamics to practical engineering problems. It has carried out a good deal of work whereby materials can be properly assessed and their behaviour in service estimated from the results of laboratory tests and experiments. Thus, considerable attention has been accorded to the strength of various steels and light alloys under rapidly repeated or fluctuating stresses, since the majority of failures of modern high-speed engines and machines in service are due to stresses of this kind. The work has provided detailed information of immediate value in engineering design, and the deleterious effects of the stress concentrations produced by screw threads, fillets of small radius, keyways, oil holes, unmachined or poorly finished surfaces, etc., are now well known. The strength of materials has also been examined from the more fundamental point of view, and the mode of deformation and fracture of single crystals of various metallic materials, both under simple and repeated loading conditions, has been studied in considerable detail. Most of the work of this Division on strength of materials, creep, and stress analysis and some of that of the Metrology Division are to be transferred to the new Mechanical Engineering Research Organisation at East Kilbride near Glasgow, Scotland.

The essential tests of nearly every new heat-resisting material used in British aircraft engines during the war were made in the Engineering Division of the Laboratory. Special creep testing machines have been developed for these tests, and a dead weight primary standard of 50 ton (50,800 Kg.) capacity is now available for the accurate calibration of tension and compression testing machines used for routine tests on engineering materials. Extensive analytical, and some experimental, work on the use of sheet metal in aircraft structures has been carried out, and during the war investigations were also made, in conjunction with C.R.L. of reinforced plastics, and of the very light core materials used in conjunction with metals and plastics in modern sandwich constructions. An air-conditioned laboratory, with controlled temperature and humidity and equipped with special testing apparatus, was established for this work.

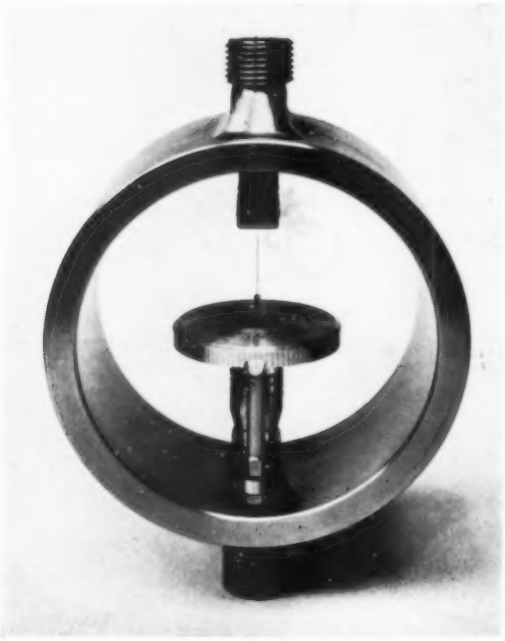
During the war years, much attention was paid to armament design problems, whereby improved performance of various weapons was achieved. In the experimental work, very valuable information was forthcoming from the use of electrical resistance strain gauges developed and made in the Division. They enable the stresses existing in engineering components under load to be determined, and thus provide an immediate check on the previous stress calculations and the margin of safety available. The Engineering Division was closely associated with the initial experimental work on the Pluto project, whereby millions of gallons of petrol were pumped through pipe lines under the English Channel, and was also responsible for the design of the high-pressure hydrogen cylinders used for the balloon barrage, and for a successful method of dealing with delayed action enemy bombs; the deformation and penetration of armour plate was also studied.



View of 50-ton dead weight primary load standard.

Over a period of years, the Engineering Division has played a prominent part in the application of the principles of fluid dynamics to engineering practice and has carried out much pioneer work on the use of small-scale models for the solution of full-scale engineering problems. In

* Included from page 72 of the August issue.



Proving ring calibrated in 50-ton dead weight primary load standard used for verification of testing machines.

1942, a 1,500 h.p. 11 in. square supersonic wind tunnel was designed and built for experiments on projectile models up to 2 in. in diameter, at air speeds up to $2\frac{1}{2}$ times the velocity of sound. Results obtained from experiments in this tunnel have been of value not only in relation to problems in ballistics and high-speed flight, but also in the general development of gas dynamics. The supersonic flow work has now been transferred to the Aerodynamics Division. A further recent development, of interest to civil engineers, is the construction and use of tidal models for the study of water flow, navigation and silting problems in river estuaries. This work originated in the Engineering Division, but in 1947 it was taken over by the newly-formed Hydraulics Research Organisation, under the direction of Sir Claude Inglis.

Extensive researches were carried out in the Engineering Division on the theory and practice of lubrication, on the design of ball and roller bearings for high speeds and loads, and on boundary lubrication and surface friction. The lubrication laboratory is fully equipped with large and small bearing testing machines and novel ancillary apparatus; the two largest machines are of 75 h.p. and can be used for endurance tests on ball and roller bearings for shafts up to 6in. in diameter and for speeds up to 15,000 r.p.m. To facilitate the study of the motion of the balls at various angles of application of load, a slow-speed angular contact bearing has been constructed having transparent races. The speed of this model can be varied between 0 and 60 r.p.m. and the angle of application of load between 0° and 90°. Since 1949, this work has been carried out at Thornton Hall, near East Kilbride, this being the first section of the Division to move to Scotland.

At a time when it is imperative both to conserve materials and to make the best use of those available, the photoelastic method of stress analysis helps the engineer to produce designs which have adequate strength for the purpose in view, and yet are not unnecessarily strong. Effect of two- and three-dimensional loading can be studied from the photoelastic patterns using transparent models of parts and the Engineering Division has developed a photometric technique for measuring the stresses. The use of this technique increases the accuracy attainable by a large factor and permits the employment of special methods for determining the magnitudes and directions of stresses.

Investigations are in progress into size effect and stress concentration in fatigue. Ever since the discovery of the weakening effect of fluctuating loads on the strength of materials, certain anomalies and discrepancies have been noted due to fundamentals not yet clearly understood. With a cyclical variation in the load applied, the fatigue strength depends not only on the shape and size of the specimen, but also on the type of stressing involved. Both the greatest induced stress and the area over which the greatest stress acts are of importance. The acquisition, by the Division, of large fatigue testing machines has made possible an investigation into the effect of the actual physical size of samples on the fatigue strength. Extremely damaging effects are frequently encountered when a change of section occurs; the ratio of the fatigue strengths without and with the change of section—the "stress concentration factor"—may be quite high. Such effects are being studied over a range of sizes and with various forms of notch; one notch of great practical importance is, of course, the screw thread. The fatigue strength of various forms of screw thread is being investigated with special reference to the unified thread form proposed for use in the Commonwealth and the United States.

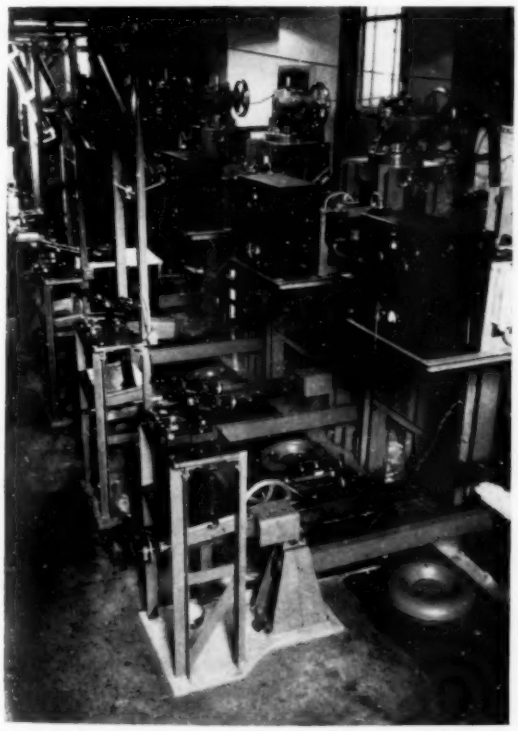
A strain-actuated electronic trigger has been designed, and is made to operate a control or alarm signal when the strain on any member of a structure or machine exceeds a predetermined value. Resistance strain gauges are attached to the member and are connected to form an A.C. bridge network. When the strain in the member is increased, an out of balance voltage is produced across the bridge which is amplified in the instrument and is arranged to trip an electronic trigger stage when a specified value of strain is reached. The main features are the high speed at which the trigger operates and the small increase in strain required. The latter need only last for 1 millisecond, since the trigger operates electronically, and the magnitude can be as small as 5 parts in 10^7. It is expected that this instrument will have a wide application as a protective device on machines and static structures where the imminence of an unsafe condition may be accompanied by an increase of linear strain in one element of the machine.

It has lately become necessary to pay special attention to the study of fatigue properties of metals at various temperatures, owing to the steadily increasing temperatures to which metals are being subjected, and to the existence of vibration stresses of appreciable magnitude in prime movers and other plant of present-day design. Failure by fatigue is a function of both the alternating stresses applied and the number of cycles of application of the stress, as well as of the magnitude of any superimposed static stress. The latter stress may be high enough to produce significant creep and failure may eventually occur by creep rather than by fatigue. Research into the relative importance of these two mechanical properties involves experiments at various

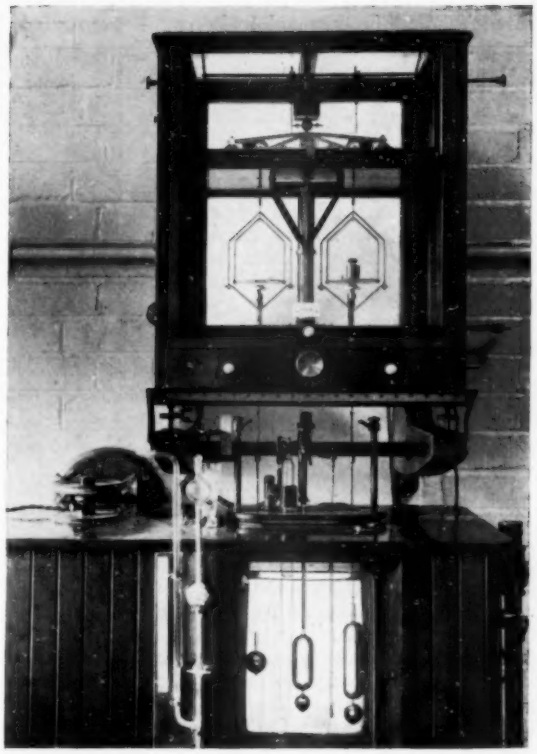
temperatures, and the study of factors such as the effects of cyclic speed, intermittent stressing, metallurgical changes, notch sensitivity and high temperature corrosion requires attention. Various testing machines have been constructed for this research, including special high-frequency types.

The efficient operation of modern power plant such as steam and gas turbines at high working temperatures requires that the structural materials used shall be capable of withstanding considerable stresses without undue deformation, both instantaneous (plastic strain) and continuous (creep strain), which might otherwise lead to severe distortion of the working parts and, perhaps, complete failure. The apparatus installed in the Creep Laboratory is devoted to the study of plastic-strain properties and creep properties under both simple and complex stress conditions, and with the object of obtaining information concerning the fundamental relations between the variables of stress, strain, temperature and time, and also of ascertaining suitable working-stress/temperature data for various engineering applications.

Testing methods used for metals are not, in general, suitable for reinforced plastics, because the latter are normally weaker and less ductile than the former. In addition, the plastics, being made of layers of reinforcement bonded together by resin, cannot be considered isotropic, and their mechanical strengths depend on the direction in which the stress is applied. Various special testing methods have been devised for determining mechanical strengths of such plastics, particular attention being paid to measurements of interlaminar strength, that is, the ability of such materials to resist forces that tend to split the laminæ apart.



View of the creep laboratory showing the double lever system used on the 5-ton testing machines. The "black boxes" contain the thermostatic control apparatus which ensures a maximum temperature variation of ½° C. at 800° C.



Hydrostatic balance and bath for the precise determination of the densities of liquids, particularly when calibrating the N.P.L. standard hydrometers.

Electricity Division

Magnetic tests and researches come under the province of the Electricity Division, with Mr. R. S. J. Spilsbury as Superintendent. They include the determination of the properties of permanent magnets, the examination of magnetic steels, the measurement of energy losses in transformer iron, the investigation of materials under weak magnetisation and magnetic study generally. Work is also under way on the properties of insulating materials at audio- and radio-frequencies. Investigations on methods of determining the errors of instrument transformers and on the effect of proximity of A.C. cables on the electrical losses have been undertaken for the electricity supply industry, and a considerable amount of work is being carried out for manufacturers of transformers and cables to determine the ability of high-voltage equipment to withstand surges.

The Electricity Division is making a study of the relation between dielectric properties and chemical structure for a series of pure materials representative of those of actual or potential importance in industry. Among materials recently examined are silicone liquids and an aniline-formaldehyde resin. Although the silicones are almost perfect dielectrics at frequencies up to 100 Mc/s. they show quite high power factors at 3,000 Mc/s. The explanation is to be found in molecular orientation with a relaxation time which increases at first with viscosity or chain-length of the material, but which tends towards a constant value for very long

chains. The aniline-formaldehyde resin, as normally used, shows maximum values of power factor at frequencies which point to molecular relaxation times of the order of 1 microsecond at 20° C. On drying the material, however, these maxima disappear, and they must, therefore, be ascribed to absorbed water, although the quantity is shown by weighing to be exceedingly small. The relaxation is thus much greater than that for liquid water but about the same as that for ice. The power factor of the dried resin, although free from peaks, is high compared, for example, with that of the silicones and hydrocarbons, so that a considerable molecular polarisation must be assumed to exist, with times of relaxation distributed over a wide range, a condition which seems to be associated with resins of a cross-linked structure.

In electrical equipment the stress cannot, in general, be confined to solid insulation, but is also applied to the surrounding gaseous or liquid dielectric. Breakdown usually begins by discharges in this immersion medium and may be completed by a path passing over the surface of the solid dielectric, or by a puncture path penetrating the solid insulation. Factors affecting the breakdown of combined solid and liquid dielectrics are being studied with a view to providing data on puncture and flash-over of use to designers. Materials at present under investigation are pressboard and phenol resin bonded paper in transformer oil.

In this room a number of different types of measuring machines sent in by manufacturers are being carefully tested against accurate N.P.L. standards.

The Metrology Division

The Metrology Division under Mr. F. H. Rolt, is responsible for the maintenance of accurate standards of length, mass and time, and of the more direct derivatives of these such as area, volume, density and pressure. The Division acts as the bridge between the national standards of length and mass and the accurate worker in science and industry. Through the Standards Department of the Board of Trade, commerce is reached also. A balance built in the Division especially for the comparison of the most important mass standards shows the remarkable accuracy of about ± 0·001 mg. when weighing kilogrammes. Finer accuracy is secured with smaller balances, and when necessary, weights up to 50 kg. are checked with certainty to a few milligrammes, such is the range and precision of the balances maintained. New developments in balance design and construction are continually studied. The introduction of non-magnetic nickel-chromium and 25% Cr 20% Ni austenitic stainless steel for good quality commercial weights was first recommended by the Metrology Division, and their recent comparative tests on a number of types of weights in the corrosive atmospheres of chemical laboratories have shown that the protective coating on rhodium-, platinum-, or chromium-plated weights should be at least 0·015 mm. in thickness in order that comparable resistance may be expected. Even then it should not be assumed without proof that a given weight is stable.

Of primary importance in the category of measurements required in precision engineering is the calibration of reference standards, of the types having flat, parallel ends, as well as those of cylindrical and spherical forms. In general these are compared with standard gauges of similar types by mechanical measurement, but reference slip or block gauges within the usual range of sizes can be calibrated by direct measurement in terms of wavelengths of light to an accuracy of one-millionth of an inch. Special discharge lamps are now available which contain a pure isotope as the light-emitting substance. These lamps provide monochromatic light of far superior quality for the interferometry of length than is obtainable from the isotopic mixtures usually present in the natural elements. Indeed, the fundamental yard and metre length units may soon be defined in terms of the wavelength of light emitted by one of these pure isotopes, such as mercury–198 or krypton–84. The interferometric technique may also be used with radio waves of 1·25 cm. length to measure distances of several metres, and an application of this technique is being made, in the first instance, to determine the velocity of propagation of electromagnetic waves.

Precision angle block standards are calibrated to an accuracy of 0·5 second of arc, and are employed in the testing of circular dividing apparatus and other angle measuring devices. All sorts of precision measuring equipment, including optical projectors (for the examination of form or contour), and engineers' small measuring tools and gauges, are tested and special investigations made on new types. To assist manufacturers and users of gauges, descriptions of methods and specially designed equipment for testing many classes of gauge are given in three N.P.L. publications.*

The Metrology Division has equipment for complete examination of all types of gears, splines and gear cutting hobs (including shaving cutters), and several types of portable appliances have been developed for the

* "Notes on Screw Gauges," 5th edition, issued 1944.
"Notes on Gauge Making and Measuring," issued 1942. A new edition is now available.
"Notes on the Use of Circular Dividing Apparatus for Angular and Linear Measurement," issued 1945.

examination of gear hobbing machines and of large marine gears. Tests of surface finish are undertaken, and development work is proceeding with the object of improving methods and equipment for recording and analysing the results of surface finish measurements.

By using the technique of high-speed photography, the Metrology Workshop has made a further advance in the dynamic method of measuring errors of machine tools whilst running. A particular experimental application of flashlight photography concerns the display of progressive pitch errors in the saddle movement of a screw cutting lathe. To this end, a specially divided glass scale of precision quality is mounted on the lathe saddle. Variations in the linear movement of the saddle relative to the rotation of the headstock are indicated by the inequalities in spacing of a series of photographic impressions recorded by a stationary camera. For each successive revolution of the lathe headstock, the lamp unit is flashed instantaneously by a contact switch and the ultra-high speed of the lamp makes it possible to photograph the precise position of each scale graduation. This technique is being considered for measuring errors in the hob-saddle traverse of large gear hobbing machines employed for cutting marine reduction gears.

The Metrology Division is also developing a method for obtaining the statistical frequency distribution of aperture sizes in mesh sieves. By combining the optical projection of the sieve with photoelectric assessment of the aperture sizes, it is hoped that it will be possible to measure and classify several hundred apertures rapidly without undue strain in the operator.

The tests provided in the Metrology Division for good quality stopwatches are of interest in that they cover separately the various contributions to inaccuracy, including mechanical errors of starting and stopping, rate error in different positions and temperatures, and the effect of the condition of winding. Time measurement has been greatly facilitated of recent years by electronic techniques, and an example of this is the impersonal photoelectric apparatus now used to enable a precision watch to register instantaneously and accurately to a few milliseconds its own error relative to a standard clock.

A photocell technique, applied in an ' optical probe ' is also employed in a primary standard barometer of range zero to 900 mm. of mercury, now under development and likely to reach an accuracy comparable with that of the present N.P.L. primary barometer which measures ordinary atmospheric pressures only. On such instruments depend ultimately the realization of the international temperature scale to the accuracy demanded by freezing point criteria of the purity of chemical compounds.

There has also been built a temperature control plant for studying the basic principles of automatic close-loop control such as is used in industrial processing for controlling such variables as temperature, pressure, liquid flow, etc. The control action is continuous, and is based upon the measured deviation of the temperature from the desired value ; the proportional integral and derivative modes of control can be employed separately, or in combination, and their effectiveness investigated in the presence of time-lags of various degrees. The behaviour of the plant following a sudden disturbance or under the influence of sustained harmonic changes can be studied.

Ultrasonic Soldering of Light Metals

(*Continued from page* 116)

effect " of the material used as a conductor is then very apparent. It has been found that if a soldering tag is soft soldered to an initially tinned light-alloy chassis a sound joint with constant electrical properties can be achieved. When chassis are required to be assembled on a mass-production scale, disorganisation of an assembly line due to the changeover of soldering irons can be avoided by pre-tinning the chassis at the required point of jointing. The chassis can then be handled for jointing connections using a normal soldering iron.

Fig. 8 shows a small electronic assembly mounted on an aluminium chassis in which the mounting strip for resistances and an earthing tag have been soft soldered to the chassis. In many cases where extreme structural strength is not required, the chassis itself can be soft soldered together ; corners, mounting brackets and components can be soldered in position as required.

Finally, an important application is in the hermetical sealing of aluminium cans. Where the numbers produced do not warrant the cost of expensive dies for deep drawing, containers can often be fabricated from tubular sections and sheets by the use of soft soldering. In the manufacture of " potted " components it is possible to soft solder the lid of the can in position if a small band of tinning is arranged on the inside and outside of the can by dipping into an ultrasonic bath. The pre-tinned aluminium lid can then be soldered in position after the component has been inserted.

Conclusion

It will be seen that aluminium and its alloys can be employed to a far greater extent than at present if ultrasonic tinning and soldering is employed. There are obviously limitations to its application and the method cannot completely replace the use of welding and riveting techniques. However, in many cases the process is economically sound and can solve many existing difficulties. Many of its disadvantages may eventually be overcome by further development work on new solders and improved methods of applying cavitation erosion to the cleaning of metal surfaces, but it is considered that the process may stimulate wider use of light alloys in the electrical and structural industries. With the increasing cost and scarcity of copper, aluminium can well prove to be a most useful metal as an economic and satisfactory replacement for copper in the transmission of electrical power and its light weight and durability can be of the utmost importance in the aeronautical and structural engineering industries.

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Surface Conditions and the Creep of Extruded High-Purity Lead

By R. C. Gifkins,* B.Sc., A.I.M.

A surface condition which sometimes occurs in extruded lead and lead alloys is shown to exert no effect on the creep characteristics of the metal.

A SURFACE condition of extruded lead and its alloys, which was described recently[1], has been further investigated in order to study the effect of its presence on creep. The condition of the surface produced during extrusion of lead was such that the X-ray back-reflection pattern consisted of sharp spots superimposed on a background ring of very small spots; however, the normal back reflection pattern consisting only of sharp spots was obtained from specimens which had been etched sufficiently to remove a shallow surface layer.

The effect of surface conditions on the mechanical properties of metals is well known and has been studied in a number of investigations; for example, Dietrich[2] found that the presence of a highly-oriented layer on the surface of rolled magnesium and certain other metals produced a lowering of resistance to bending. It was thought, therefore, that an investigation into the effect of the presence of the extrusion layer on the creep of lead would be of interest; further, it was known that the surface layer was sometimes formed during the commercial extrusion of lead alloys, so that the results of the tests could be of practical interest. Also, some preliminary tests with high-purity lead had yielded variations in creep behaviour which could be due to the surface condition.

Three sets of experiments were made. Firstly, before it was realised that the extrusion effect was superficial, a series of tests with specimens annealed for various times at 100° C. was started. It was found that progressive extension of the time of anneal at 100° C. resulted in a parallel delay in the onset of recrystallisation, and this phenomenon is being confirmed and further studied on the basis of a tentative explanation.

The other two sets of tests will be briefly described here. In these, the creep characteristics of a group of specimens which retained the surface layer formed during extrusion were compared with those of a similar group whose specimens had been carefully etched to remove the layer. In one set, creep was developed by direct loading in tension, and in the other, the specimens were suitably shaped, so that when tested by bending the skin stress was uniform over the gauge length.

Before testing, the specimens, which were made from high-purity lead, were annealed for 2½ hours at 100° C.; details of the purity of the lead and of relevant experimental techniques have been given elsewhere.[3]

The group of specimens directly loaded consisted of two etched and two unetched at each of the three stresses—500, 400 and 300 lb./sq. in.; the tests at the lowest stress are still in progress, but the others were all carried through to the fracture of the specimens. In the bend-tests the initial skin stress was 500 lb./sq. in.; two etched and two unetched specimens were tested and the experiments terminated when the deflection became too small to measure conveniently. In none of the tests was any systematic variation of creep-rate or other creep characteristics with surface condition found, and subsequent observations with extruded lead-tin and lead-thallium alloys confirm this result. The rates of strain during minimum creep ranged from 42 to 3×10^{-4} mm./mm./day.

These experiments have been described in some detail because the result is somewhat unexpected and it seemed desirable to define the conditions of the tests without ambiguity. It must be concluded not only that the surface layer formed during extrusion but that the surface conditions in general exerted no influence on the creep of lead at these rates of strain, for numerous fine and shallow score marks on the surface of the specimens after extrusion were removed by etching, which produced a polished, flat surface, free from pits.

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New Exhibition Room

A new exhibition room has just been completed at the works of Aero Research Ltd. The function of the display is mainly to illustrate the wide range of uses of synthetic resins in modern industry. Thus, "Aerolite" glue is featured for woodworkers while, of greater interest to engineers, "Redux" is shown in its applications for bonding metal to metal, to wood, to rubber, thermo-setting plastics and friction linings. "Araldite," primarily an adhesive for metals and ceramics, is also displayed as a surface coating resin, as a casting resin for the electrical industry and as a cold-setting filler. Separate panels illustrate resins for wet-strength paper and for the manufacture of sandcores for foundries. Working models and demonstration units include a film-strip projector, a testing machine for glued joints, a radio-frequency heating generator and strip-heated jigs.

Radiant Warming for Modern Factory

By Frank H. Slade, A.M.I.Mech.E.

AN increasing number of new factory buildings are being equipped with radiant warming systems, thereby achieving working conditions of health and comfort that are conducive to efficiency, a fuel consumption lower than that of other types of heating system and, through the evenness of the temperature existing at floor and ceiling level, i.e., not more than 2° F. differential, considerable reduction in dust hazards.

Installations in buildings of the multi-floor type usually take the form of embodying heating panels in the structure, principally as ceiling panels, serpentine coils embedded in the concrete floor construction, with a normal thickness of plaster on the underside, forming the heat radiating surface in the ceiling, while the concrete serves as a heat distributor and heat retainer. In existing buildings and shed-type factories, it may not be possible to supply embedded panels and as an alternative to this the Sunzway radiant panel units have been developed. These, preferably fixed in the ceiling and used with the existing heating supply, usually low pressure hot water if servicing a building, possess most of the advantages of the embedded panel warming system.

Fig. 1.—As illustrated by this view of the Board Room, invisible embedded panel warming does not interfere with decorative treatment and obviates obstructions and dust-pockets caused by other forms of heating equipment.

The panel units are of rigid steel construction, of minimum weight, and are easily fixed by special brackets. In addition to the foregoing application they have been found useful in shed type factories, stores and other premises where well-diffused and effective warming is required. In such cases they may be fixed horizontally in the roof or vertically on walls or stanchions, and if desired double-sided units may be employed to radiate in opposite directions.

Fig. 2.—The 8 ft. × 4 ft. single-faced pattern Sunzway radiant panels are shown fitted vertically to the walls in this part-view of one of the process shops.

Radiant warming is employed at the new Ruislip Factory of Messrs. George M. Whiley, Ltd., and this is of particular interest in that both of the preceding methods of installation are incorporated. This modern factory, designed by Mr. E. H. Firmin, A.R.I.B.A., 11, Park Road, London, N.1 consists of ground floor factory space with offices at first floor level, and the heating system, designed and installed by Messrs. Richard Crittall & Co., Ltd., 151, Great Portland Street, London, W.1, comprises invisible embedded panel warming in the offices and entrance hall, medium temperature Sunzways in the factory and canteen, and radiators in the works' lavatories, etc.

Office and Factory Warming

The design requirements were for the provision of a temperature of

65° F. throughout the offices and factory when the external temperature is 30° F. This is secured in the offices by means of some 3,000 sq. ft. of embedded ceiling panels constructed from ½ in. diameter special bending tube at 6 in. centres. As illustrated in Fig. 1, these, in being embedded in the ceiling, do not detract from the aesthetic appearance of a room, do not occupy valuable floor space, and eliminate the formation of dust pockets.

Control of the panels installed in each room, and thus of the room temperature, is secured by individual control valves of the double regulating pattern provided where possible at or near skirting level in wall boxes. Whilst this arrangement ensures that the apparatus can be permanently regulated, it also allows for individual opening and closing of the apparatus by the occupants of the various rooms, without interfering with the regulation of the system.

Fig. 3.—A horizontal, or overhead, location is adopted for the Sunzway panels in this particular process shop, in view of the large expanse of windows and roof glazing, and lack of vertical fixing space due to the presence of equipment.

Equable working conditions, and the even temperatures required by the various processes carried out, are secured in the factory building by means of 71 8 ft. × 4 ft. single-faced pattern Sunzway radiant panels fixed at high level and, as shown in Figs. 2 and 3, in both the vertical and horizontal (overhead) positions. Each of these panels is provided with control valves to permit both individual control and permanent regulation. These panel units, located overhead, are also used to provide healthy and comfortable conditions in the canteen, whilst in the works lavatories two radiators of the Neo-Classic pattern allow equivalent amenities.

Boiler Plant

The boiler house is at present equipped with one Britannia pattern Ideal Boiler, rated at 1,090,000 B.Th.U.s per hour and supplying hot water at a flow temperature in accordance with the requirements of the Sunzway installation. The boiler is oil fired and for this purpose is fitted with a fully automatic oil burning unit, of Messrs. Combustion Co., Ltd.'s manufacture, designed for use with oil having a viscosity of 220 sec. Redwood No. 1 at 100° F.

One oil storage tank of 4,500 gallons capacity provides for a three weeks maximum demand, and this has been installed adjacent to the boiler house. The tank is filled through a 3 in. filling connection run from a convenient position in the roadway, and the supply to the burner unit is through an oil supply line fitted with a Duplex strainer. A quick cut-out fire valve is also incorporated in the oil line to the burner to ensure the cessation of oil flow in the event of a fire in the boiler house.

One circulating pump of the Mo-pump pattern, made by Messrs. Rhodes, Brydon & Youatt, Ltd., is installed to cater for the Sunzway panel warming system, and the boiler-house equipment is completed by a similar pump for the embedded panel, or office warming system.

Flow Temperature Control

The provision of two separate pumps was made necessary by the difference in temperature at which the Sunzway and embedded panels operate, the former requiring a mean hot water temperature of 180° F., and the latter a mean hot water temperature of 100° F. Therefore, as the boiler is designed to operate at the flow temperature required by the Sunzway system, means must be adopted to mix the hot water direct from the boiler with a proportion of colder return water in order to secure the lower temperature level desired in the embedded panels, the water being handled at each desired temperature by a separate pump.

Mixing is accomplished by means of a branch connection, fitted with a modulator which regulates the mixing of the flow and return water to reduce the flow temperature in accordance with the demands of the panel warming system. The modulator included is of the triple port pattern, actuated by a multiple thermostat fitted in the main flow to the panel installation, the thermostat being set manually to a predetermined temperature and also provided with a central automatic control system for maintaining predetermined workshop temperatures. A high temperature fusible link valve is also provided to give visible warning should the temperature of the water supplied reach a temperature higher than required.

In conclusion, the writer wishes to express his appreciation to Messrs. George M. Whiley, Ltd., Mr. E. H. Firmin, A.R.I.B.A., and Messrs. Richard Crittall & Co., Ltd., for their kind collaboration in the preparation of this article.

Silicate Mineral Structures

THE Autumn Conference of the X-ray Analysis Group of the Institute of Physics, which will be held in the Lecture Theatre of the Institution of Electrical Engineers, Savoy Place, London, W.C.2, will have as its subject "The Structures of Silicate Minerals." At 2-15 p.m. on Friday, November 2nd, the discussion will be on calcium silicates, whilst that on Saturday morning (9-45 a.m.) will cover clay minerals and asbestos. On the Friday evening, at 8-30 p.m., Dr. W. H. Taylor will deliver a lecture on "Felspars."

CO-OPERATIVE RESEARCH ACTIVITIES

Recent years have seen a considerable expansion in co-operative research as carried out by research associations set up to function on behalf of a particular industry or group of industries. The value of such an arrangement is obvious in the case of industries consisting, in the main, of large numbers of small firms, none of which could afford to maintain adequate research organisations, and it is not surprising, therefore, that some of the earliest associations were formed to serve industries of this type. To-day, however, one of the largest associations in the country is concerned with the problems of an industry comprising mainly a relatively small number of large firms, most of which have their own research establishments. There are, however, many problems, including those arising from changing economic and technical conditions, which are common to the industry as a whole, and it is to these that attention is directed.

There is no doubt that the research associations, whatever the industry they serve, have a most important part to play in the national economy. Now that considerable effort and money must be expended on the rearmament programme, it is more than ever essential that our exports should be competitive in quality and cost—a condition which calls for constant research and development in order to improve products and to reduce costs by achieving greater productivity. Not only is there necessity for economy in the use of labour, but the raw material situation, particularly in the case of metals, is such that every effort must be made to effect economies in the use of certain strategic materials—a factor which is reflected in some of the research work in progress to-day.

In the following pages are presented accounts of the work of a number of research associations in the metallurgical field.

The British Iron and Steel Research Association

The last year has seen an increase in the laboratory space available, but much of the work of the British Iron and Steel Research Association will still be carried out, and necessarily so, at the works of member firms. Brief reference to the work of the several Divisions is made in this article.

ALTHOUGH space precludes the mention of more than a few of the problems receiving attention from the Association, the account presented here gives a general picture of its activities. Fundamental work takes its place side by side with pilot plant experiments, full scale field trials and the investigation of problems arising from changing economic and technical conditions, such as the effect of increased pig iron/scrap ratio on the operation of open-hearth furnace plants.

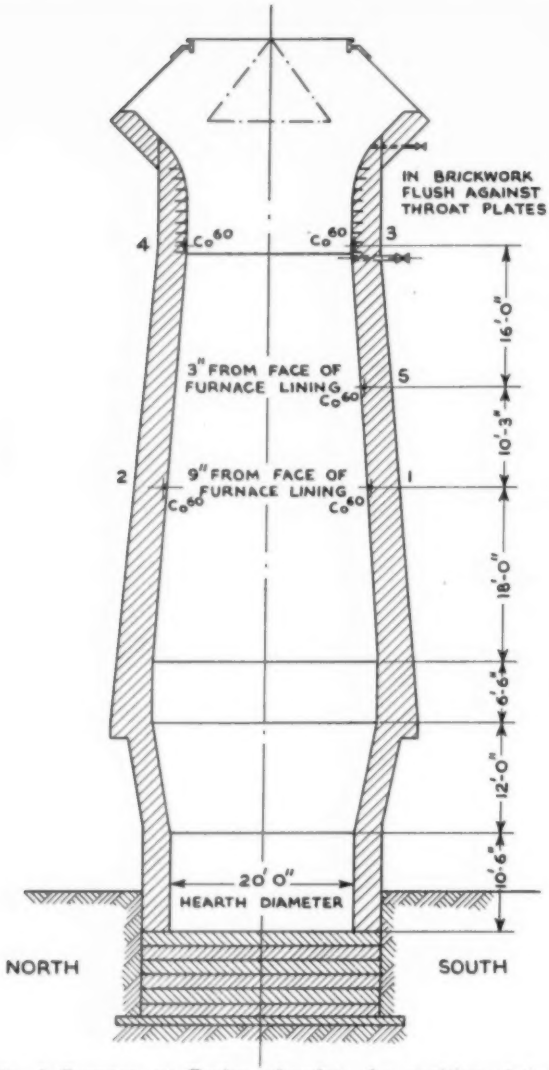
Ironmaking

The use of radioactive tracer elements in blast-furnace exploration has been mentioned in previous reports, where a technique for measuring gas velocity by this means has been described. Another use has now been developed by B.I.S.R.A. with the help of a number of member firms, and though the technique is in a comparatively early stage there are indications that it will prove a useful tool. In this, radioactive tracers are used to measure refractory wear on a driving blast furnace.

Cobalt 60 is used as a source of X-rays, since it lasts a long time, gives a strongly penetrative radiation and is quickly and cheaply produced from Cobalt 59 in an atomic pile. In the stack, bosh or tuyère belt where a counter can be brought within about 2 or 3 ft. of the cobalt pellet, radioactive tracers have been built into the lining bricks of five furnaces, their activity being detected from outside the shell. Installations can also be made in the carbon bricks of furnaces where the counter cannot be brought near enough, for when wear on the hearth releases the pellet into the iron all the iron becomes very slightly active. If samples are kept at each cast then by presenting the samples to a counter, weeks later if necessary, it will be possible to determine when the pellet entered the iron. It must be emphasised that the counters are extremely sensitive and the activity envisaged is only roughly equal to the effect of adding the luminous paint from one wrist watch to every hundredweight of iron.

Pellets have been installed in blast furnaces at the works of Messrs. Stewarts & Lloyds, Ltd.; Appleby-Frodingham Steel Company; Colvilles, Ltd.; The Sheepbridge Co., Ltd. and Dorman, Long & Co., Ltd. Fig. 1 shows the positions selected on Messrs. Stewarts & Lloyds, Ltd.'s furnace. At the Sheepbridge Co., Ltd.'s furnace a 5 millicurie pellet has been placed in the stack at the junction between the carbon hearth and the brick stack. This is detectable at the shell, because the distance is not great. They are also using 2 millicuries in an open alumina crucible in a firebrick laid as part of the protective course on the top of a carbon hearth. The amount of 2 millicuries was chosen as being just enough to detect and not enough to be objectionable, bearing in mind that the pellet might enter the metal in the first tapping, which might be only 20 tons, and that the metal is cast into pigs and might suffer very little dilution before being cast by foundries. This pellet had not appeared in the metal within the first three weeks after blowing in.

Another aspect of blast-furnace research concerns stereoscopic ciné films taken through two viewing windows 4½ in. apart, at 3,000 frames/second. By showing the stereoscopic film in slow motion (16 frames/second) the particles of "dancing" coke, etc., can be followed through part of their travel, and their sizes and



No. 4 Furnace at Corby, showing the position of the Cobalt 60 pellets

distances from the tuyère nose can be measured. From such measurements, it is hoped to gain information on the rate of burning of the coke particles, and on the gas-flow conditions and the position of fixed masses in the furnace.

Steelmaking

An example of co-operative work affecting production methods is that done on the instrumentation of open-hearth furnaces. Experience in the whole industry has been contributed to a common pool through the appropriate B.I.S.R.A. committee, and as a logical extension of this the United Kingdom now has some 12 open-hearth furnaces operating with automatic roof temperature control, a greater number than in any other country. The greater output and fuel economy thus achieved are exemplified at one works where an automatically controlled furnace is averaging 113 tons of steel per week more than it did on manual control, for just about the same expenditure of fuel.

"The Instrumentation of Open-Hearth Furnaces," by the Open-Hearth Instruments Sub-Committee, which is to be issued during October, 1951 by Messrs. George Allen & Unwin, Ltd., London, will be the first published handbook on the subject.

This Division of the Association is inevitably concerned with the raw materials position, and particularly with the higher proportion of pig iron to scrap in steelmaking that is becoming necessary as a result of the scrap shortage. A very successful Junior Steelmaking Conference discussed this subject on the basis of a paper by Dr. T. P. Colclough in June. It has become apparent that, unless some modifications are made to present steelmaking practices, the increase in slag bulk resulting from the need to use more pig iron will seriously lower the output of open-hearth furnace shops. Possible modifications of practices to which special consideration is being given are slag flushing, active and inactive mixer operation, the desulphurising of pig iron, and pre-blowing methods of desiliconising pig iron. An early and important conclusion reached in the study of mixer practice is that the amount of stirring which takes place is more important than the actual time the metal spends in the mixer.

Several years' work on the stresses in ingot moulds culminated in a symposium published in July. It contained reports on mechanical and physical properties of mould irons and on the determination of surface stresses in moulds, by calculation from the measured strains occurring during use. Repeated loading tests by B.C.I.R.A. on mould irons showed that after about 80 cycles, failure could occur at less than 80% of the ultimate tensile strength of the iron. As the B.I.S.R.A. work showed that the stresses occurring in the mould during use often closely approach this "endurance strength," it is not surprising that moulds frequently fail by major cracking. The strain measurement work will be extended to cover other positions in the mould, to determine at which points stress concentrations occur, and also to include moulds differing in various details of design. It is hoped that data will be obtained which will make it possible to design moulds which will be less prone to failure by major cracking. As it has been calculated that the industry spends some £4,500,000 on ingot moulds in a year (allowing for sale of scrap) the importance of this field of work is evident.

Mechanical Working

In the field of steel fabrication, three new developments also bear on material shortages. The automatic control of strip gauge in rolling promises an increase in the yield of tinplate strip and motor body sheets. A new method of automatic control based on continuous roll force measurement has been demonstrated on the Association's experimental cold strip mill. A similar method for hot strip rolling is being developed.

A new technique for preventing edge cracking in the rolling of special steels is capable of reducing the quantity of process scrap. Experiments are also well advanced on a method of dieless drawing of wire which, if successful, should reduce the demand for scarce tungsten carbide. In this connection, tests are also being made on alternative die materials such as alumina for use in the continuous drawing process.

A rather different problem is that of reducing the consumption of sulphuric acid for pickling. In addition to the pilot plant (noted last year) now being built in South Wales for regenerating sulphuric acid from

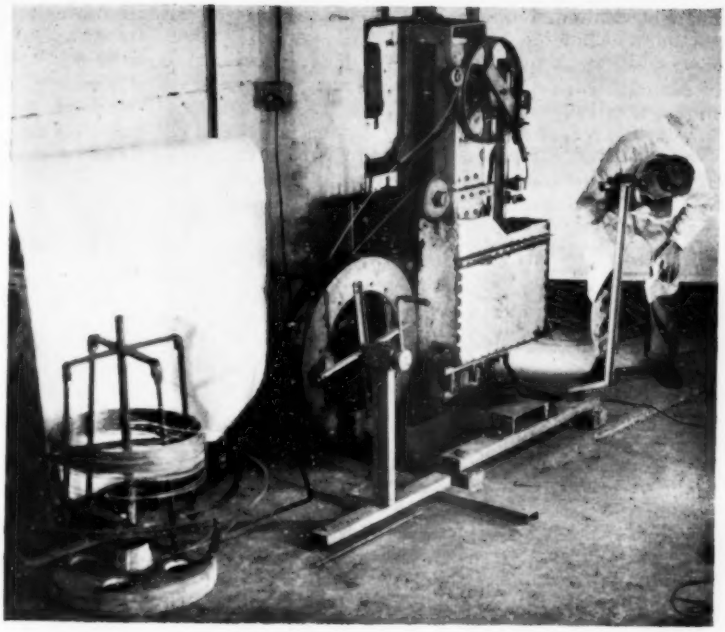
copperas, proposals have been made for immediately reducing the losses in pickling. Indications are that comparatively slight changes in practice may result in substantial saving, and works trials are in progress.

The shortage of zinc has sharpened interest in hot-dipped aluminized steel sheets, tubes, etc., as a substitute for galvanized steel and experiments are being made with various methods of hot-dip aluminizing.

Plant Engineering

A large part of the Association's engineering staff is engaged on work concerned with the handling of imported ore. The rates of ore discharge at Dagenham, Workington, Glasgow, Middlesbrough, Port Talbot and Barrow-in-Furness have been studied in detail to determine the factors affecting the turn-round time of ore ships. These ships have been selected to cover various sizes and types of equipment and different working methods.

An assessment has been made from tidal data of the extent to which ships of various tonnages can gain access to 10 representative British ports. A comparison has also been made between the sizes of ships actually using the ports and the computed maximum sizes of ships which could enter them. This has shown that considerably larger ships could be used, if other conditions such as those of chartering were favourable. An attempt is being made, by a comparison of known performance figures in relation to ship design, to assess the suitability of various classes of ships for carrying ore. In this way it is hoped to specify the important points in the design of future ore-carrying vessels. The Association's Operational Research Section has assisted in this work by analysis of 2,500 cargoes during 1948–9 to determine the effect of such factors as unloading equipment, type of ore, and type of ship, on unloading rate; at the same time the relationship between wharf occupancy and delay in waiting for a berth is being considered and cost factors are being obtained and analysed to determine the effects of various methods of speeding up ship turn-round and to assess their economic merits. The handling of materials inside the steelworks is an allied subject. Following previous work on rail traffic analysis, field trials on four makes of V.H.F. transmitter/receiver radio equipment intended for use on works' locomotives have been made with the co-operation of an integrated steelworks. A fixed station was established and, with the mobile unit mounted on a locomotive, measurement of intelligibility and radio coverage were made throughout the works. Results confirm that for all but the largest steelworks a 5-watt mobile transmitter is adequate. Some of the equipment at present available appears to be satisfactory in its present form for use in steelworks, and at least two works are installing such systems.



Wire drawing without dies. An experimental machine at B.I.S.R.A.'s Sheffield Laboratories, on which wire is "stretched" for reduction. It is possible to reduce the area of 9 S.W.G. bright hard-drawn mild steel wire by 50% in a single pass.

Metallurgy Division

One of the many subjects in the field of this Division is that of age hardening. It has been claimed that the addition of small quantities of vanadium or chromium to rimming steel will give a high resistance to strain ageing without seriously affecting the rimming properties. A theoretical study by the Chemistry Department confirmed that the effect of vanadium might be due to its combination with nitrogen present in the steel, and that the vanadium-nitrogen ratio might therefore be important. This is the subject of a research at Cardiff University, and it has been shown on a laboratory scale that small additions of vanadium decrease both the amount and rate of ageing in rimming steel. These experiments are being confirmed on a works scale and, meanwhile, further laboratory studies are being made of the effect of the vanadium-nitrogen ratio on the ageing characteristics of rimming steel.

Another important subject of investigation, which has now been in progress for nearly 14 years, and is nearing completion, concerns the effect of non-metallic inclusions on the fatigue properties of steels heat treated to tensile strengths of 60, 80, 100 and 130 tons/sq. in. This work has been entirely co-operative and several important conclusions are emerging, which place a new emphasis on the value of fatigue testing in metallurgical research. A fatigue testing laboratory is to be established to deal with a number of important and specific problems which arise out of the present programme and, in view of the existing lack of fatigue facilities in this country, such a laboratory will make a very real contribution to the research requirements of the iron and steel industry.

A further six standard methods of analysis have been issued by the British Standards Institution as parts 17 to 22 of B.S. 1211. Those which have resulted from the work of B.I.S.R.A.'s Methods of Analysis Committee are

Part 18: chromium in ferro-chromium; part 19: small amounts of soluble silicon in plain carbon and low alloy steels and irons; part 20: tin in highly alloyed steels (including high-speed steels); part 22: tin in ferro-tungsten and tungsten metal.

A report prepared for another committee, entitled "Magnetic and Electrical Methods of Non-Destructive Testing," which presents information about the limitations and capabilities of all known methods of these types of testing, is to be published by Messrs. George Allen and Unwin, London, next month.

The work of the Corrosion Committee is under the aegis of this division, and the technical direction of the Chemistry Department. Only one example need be taken from an extensive programme which is already widely known. An interim report on steel coal wagons shows that the use of low alloy steels, such as copper, copper-manganese or copper-chromium types should double the life of the floor plates which up to now have been made of mild steel. It is further stated that the plate thickness of the superstructure of all coal and mineral wagons might be reduced, thus resulting in a valuable economy in the dead load.

A symposium on "The Corrosion of Buried Metals" has been arranged for Wednesday, December 12th, 1951, at the Iron and Steel Institute. It is hoped to obtain useful comments on the work already undertaken by investigators and constructive suggestions about future research.

Physics and Chemistry Departments

The work of these two "common services" provides a common thread to the work of the separate divisions from which the above examples have been drawn. Much important work on the sulphur problems with which the Steelmaking Division are concerned is being done by the Chemistry Department. The stereoscopic photography technique used on the blast furnace is being developed with the help of the Physics Department, which is also continuing its work on the continuous casting of steel so that the physics of this important new technique can be studied.

During the year B.I.S.R.A. has been able to extend laboratory space in two localities. The whole of the light industrial premises in Battersea, of which Physics, Chemistry and Plant Engineering laboratories previously occupied about one quarter, have been acquired. This makes available some 43,000 sq. ft. of additional laboratory and office accommodation, which is being occupied by the Association's Plant Engineering Division and Chemistry Department, including the Corrosion and Refractories Sections.

At Normanby, near Middlesbrough, office and laboratory accommodation have been equipped in a house conveniently sited near the great iron producing area on Tees-side with easy access to the industries of Durham and Lincolnshire. This is primarily for use as a base of operations for the Ironmaking Division's field trial teams. In particular it is near the works where both pelletising and sintering pilot plants have been installed.

Work also continues on the group of laboratories being built in Sheffield, and it is hoped that the laboratory for the experimental plant will be complete by the end of 1951. Meanwhile the temporarily adapted buildings are in use for rolling mill, wire drawing, forging and steelmaking researches.

Coming of Age

A PIONEER in the application of light alloys to marine construction, Birmabright, Ltd., last month celebrated its coming-of-age with a reception at the Mayfair Hotel. Mr. E. Player, Managing Director of Birmid Industries,

Ltd., the parent company, welcomed the guests, who included representatives from the Swedish, Belgian, Danish and Netherlands Embassies, Air Comm. W. Helmore, Director of the Aluminium Development Association, and Mr. H. E. Jackson, Chairman of the Aluminium Industry Council.

Guests were given a preview of the Birmabright Stand at the recent Engineering and Marine Exhibition at Olympia, where emphasis was laid on the application of the company's aluminium alloys in marine construction. Three relatively new developments were featured: refrigerated ships, with aluminium hold linings; trawlers, in which light alloys are used for fish hold linings, stanchions, fish boards and shelves, superstructures, funnels, and radar towers; and davits for ships' lifeboats.

Solder Film Shown in Scandinavia

"THE Vital Link," the H. J. Enthoven & Sons, Ltd., colour film on solder, has now been shown to large representative audiences of the Norwegian, Swedish and Danish radio and electronic industries in Oslo, Stockholm and Copenhagen. Works managers, engineers and chemists present expressed their appreciation of the film which brought home to them in vivid fashion not only the close control of the various processes used in manufacturing "Superspeed" Activated Rosin Cored Solder, including the new coloured cored solder, but also the importance of selecting the right cored solder for any particular job. Subsequent discussion centred mainly on the soldering techniques and the many individual problems which the manufacturers have to face in this connection. The film has undoubtedly created renewed interest in this subject and has proved of value in the company's export drive.

The British Non-Ferrous Metals Research Association

By W. L. Hall, B.Sc., A.R.S.M., A.R.I.C., A.I.M.

Chief Liaison Officer, The British Non-Ferrous Metals Research Association

In the present situation, the Association, while proceeding with its long-range researches and liaison and information services, must also give help in economising in the use of scarce metals and providing substitutes. The balancing of the programme to meet these varying needs is set out below.

IT is necessary to preface this review of some of the research undertaken by the British Non-Ferrous Metals Research Association in the last two years by reference to the present acute shortage of non-ferrous metals. Special steps have been taken to assist the industry in its efforts to economise in the use of certain metals and to find substitutes. This has necessitated the deflection of staff to this work even at the expense of reduction of effort on some of the long-term researches.

The notes on the general work of the Association which follow later in the article have been arranged under various subject groupings which roughly indicate some of the divisions of the Research Department of the Association. It will, of course, be understood that lack of space prevents a complete account of the work, either published or still on the confidential list, which has been undertaken during the past two years.

The B.N.F.M.R.A. and Metal Shortage

Zinc

The severe rationing of zinc for galvanizing has made it imperative that the most efficient use be made of the limited quantity available. The staff of the Research Association have applied to industrial practice in a member's works information arising from previous work of the Association. It has been shown that the uniformity of zinc coatings applied to fabricated sheet steel articles can be improved and coatings produced having the minimum thickness consistent with satisfactory corrosion resistance. Economical use of zinc in this way, coupled with other measures designed to reduce the amount of zinc wasted as oxide skimmings or zinc-iron dross, resulted in a substantial saving when compared with practices commonly used in the industry. The improved practices were shown to other members in the industry at a demonstration arranged in the works of the member co-operating in the industrial trials, and the services of the Association's staff have been offered to assist all members in the trade wishing to apply improved techniques in production.

Nickel

The restriction in the use of nickel for electroplating has raised similar problems in another section of our membership. Members have pooled their experience on ways of reducing wastage of nickel, for example by losses as nickel salts dragged out in plating solutions on the work, and this experience has been made available to all members, and published.[1] At the same time, research is in hand to study means of improving the quality of nickel electrodeposits so that a good standard of corrosion resistance may be obtained with thinner coatings and, consequently, reduced consumption of nickel. Finally, information is being collected for the benefit of members on alternative methods which can be used for the protection of articles for which nickel plating may be prohibited, and trials of certain promising methods are in progress in the laboratories.

Reclamation of Copper and Sulphur

Many members in the wrought copper and copper alloy industries use considerable quantities of sulphuric acid for pickling, and are also interested in the best methods of reclaiming metal from the various waste products, such as furnace skimmings, which arise even when all reasonable precautions are taken in careful control of melting conditions. As a first step, the Association's staff have collected information from members, who have generously pooled their experience in, for example, recovery of copper and regeneration of sulphuric acid by electrolytic treatment of pickle solutions. This experience has now been made available to the whole industry. This survey, of course, revealed various special problems which require laboratory investigation before satisfactory recovery procedures can be recommended, and such points are receiving the urgent consideration of the research staff.

A long-term investigation, but one nevertheless related to current material shortage, has recently been sponsored by some of the Commonwealth copper producers to study new methods of extraction of copper which would permit the direct recovery of sulphur as such from sulphide ores. Many copper smelters are situated at such distances from industrial centres that the recovery of sulphur as sulphuric acid by treatment of the smelter gases, though technically possible, would not be a reasonable proposition owing to the problem of transporting large volumes of sulphuric acid over long distances. The recovery of this sulphur as the element itself by methods more direct than those at present known would therefore be very attractive.

Progress of Researches

Melting and Casting

A number of papers have recently been published giving the results of research on the solidification of castings.[2, 3, 4, 5] The purpose of this long-term investi-

1 B.N.F.M.R.A. "Conservation of Nickel in Plating," *Metal Industry*, Aug. 17th, 1951, **79**, 128–130.

2 Ruddle, R. W., "A Preliminary Study of the Solidification of Castings," *J. Inst. Metals*, Mar., 1950, **77**, 1–36.

3 Ruddle, R. W., "Correlation of Tensile Properties of Aluminium Alloy Plate Castings with Temperature Gradients during Solidification," *J. Inst. Metals*, Mar., 1950, **77**, 37–59.

4 Ruddle, R. W., and Mincher, A. L., "The Influence of Alloy Constitution on the Mode of Solidification of Sand Castings," *J. Inst. Metals*, Nov., 1950, **78**, 229–248.

5 Ruddle, R. W. and Skinner, R. A., "Heat Extraction at Corners and Curved Surfaces in Sand Moulds," *J. Inst. Metals*, Mar., 1951, **79**, 35–56.

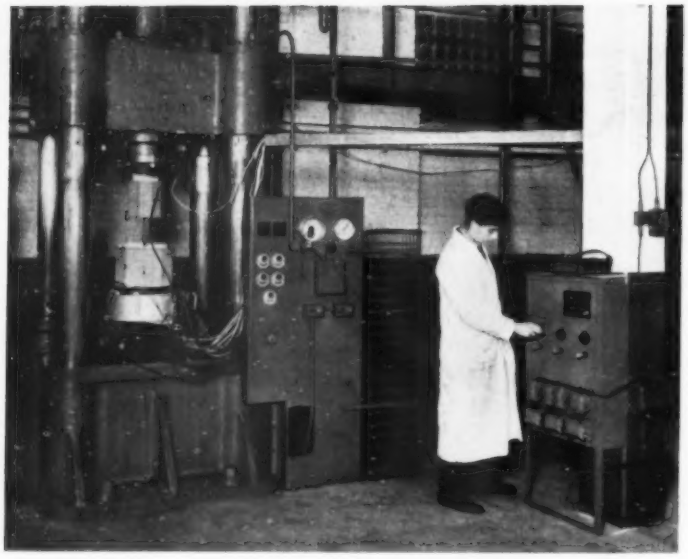


Fig. 1.—Equipment for experimental extrusion of lead. The relation between extrusion conditions and the structure of lead pipe for plumbing and chemical use is being studied.

gation is to build up a body of information on the way castings solidify, since it is clear that a complete understanding of the changes occurring from the moment of pouring until the casting is entirely solid is something every designer and foundryman should possess. This complete picture is not at present available, and in the work so far carried out the rates of heat extraction by various mould materials, and their thermal properties, have been studied; the solidification times of castings of various shapes and sizes have been observed and compared with calculated results; and the effect of corners and curved surfaces on these times has been analysed. Important sections of the work have, in addition, been concerned with the modes of solidification of various metals and alloys of different constitution, and with heat flow in the solidification of castings. This research is now temporarily in abeyance, so that the staff can concentrate on investigations of a more practical nature, to speed up the application in industry of the results arising from the Association's research on melting and casting problems in general.

An investigation on the mechanism of grain refinement in aluminium alloys[6] has shown that, when titanium is added to a molten aluminium alloy, the nuclei around which solidification commences are particles of titanium carbide structurally similar to aluminium, but that the full effects of grain refinement are only found in alloys also containing an element such as copper in solid solution. The solidifying metal then differs somewhat in composition from the melt, and the concentration gradient in the molten metal round each crystal restricts its growth. The practical effects of grain refinement on the mechanical properties of some aluminium alloy castings have been demonstrated.[7] Recent research has been concerned with improved grain refinement techniques for aluminium alloys and with attempts to apply the ideas on the mechanism of grain refinement arising from the research on aluminium alloys to the development of grain-refining techniques for cast copper alloys.

Corrosion

The widespread use of copper piping for conveying water in domestic plumbing systems is not normally attended by corrosion problems, but in certain districts localised pitting corrosion has occurred causing early perforation of pipes. It is now known[8] that for pitting corrosion to occur in cold water three conditions must obtain: (*a*) the internal surfaces of the pipe must have a carbonaceous film, or a particular type of glassy copper oxide film, formed during manufacture; (*b*) the water must be at least of moderate hardness; (*c*) a naturally occurring inhibitor, present in many water supplies, must be absent from the supply in question. Manufacturers are taking all possible steps to ensure that pipes are made without these undesirable surface films and further laboratory work is in hand on tests for the detection and identification of the substance, probably of a colloidal nature, responsible for inhibiting corrosion. Less is yet known about corrosion of copper in hot waters, except that it is usually associated with films deposited from very soft waters from moorland gathering grounds. The influence of the corrosion inhibitor on the attack of copper by hot waters is also under investigation.

6 Cibula, A., "The Mechanism of Grain Refinement of Sand Castings in Aluminium Alloys," *J. Inst. Metals*, Dec., 1949, **76**, 321–360.

7 Cibula, A. and Ruddle, R. W., "The Effect of Grain Size on the Tensile Properties of High-Strength Cast Aluminium Alloys," *J. Inst. Metals*, Dec., 1949, **76**, 361–376.

8 Campbell, H. S., "Pitting Corrosion in Copper Water Pipes Caused by Films of Carbonaceous Material Produced during Manufacture," *J. Inst. Metals*, June, 1950, **77**, 345–356.

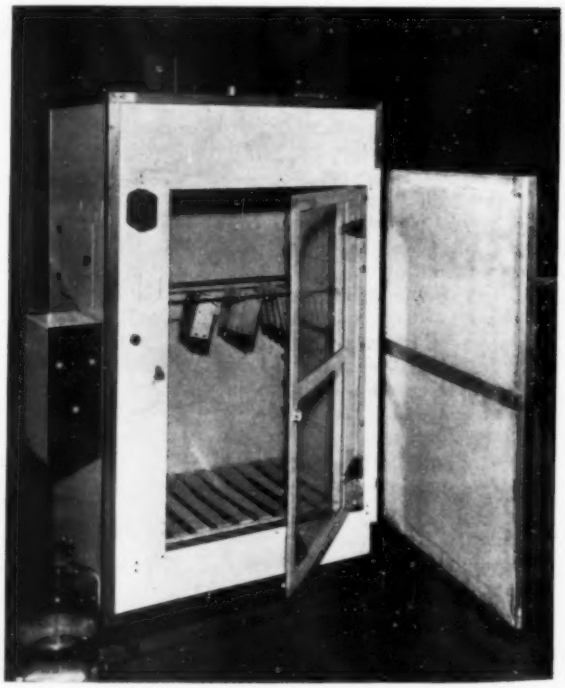


Fig. 2.—Humidity cabinet for use in corrosion studies. Constructed in the Association's workshops.

The experience of the Association and its members in research on, and service behaviour of, copper alloys used in moving aerated seawater in ships' condenser systems and the like has been reviewed in a number of recent papers.[9, 10, 11, 12, 13] The Association's work in this field over a number of years is reflected in current Admiralty and mercantile marine practice, while the copper-nickel-iron alloys containing 5% of nickel and about 1½% of iron continue to find increasing use for seawater carrying services, especially where capacity for hot working during installation is an advantage. The papers referred to also include detailed descriptions of the laboratory testing procedures used by the B.N.F.M.R.A. for the assessment of the resistance of alloys to corrosion by seawater under impingement conditions, and also for comparison of the relative corrosive behaviour of different samples of seawater contaminated to different degrees by organic compounds.

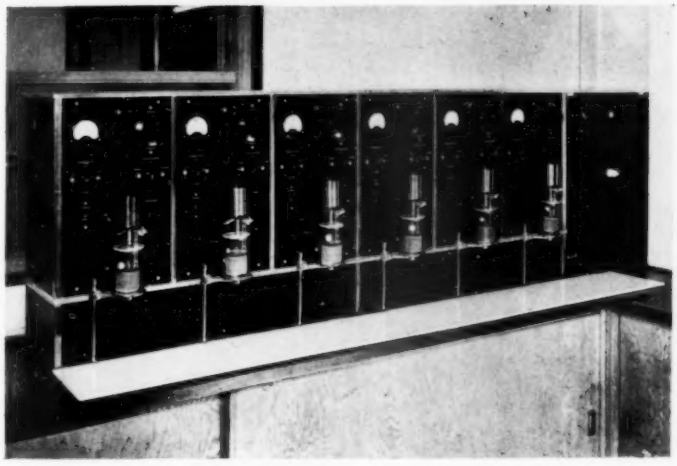


Fig. 3.—Apparatus for electrolytic separation and analysis. Constructed in the Association's workshops.

Another group of papers surveys the extensive work on the stress corrosion of light alloys which has occupied some of the Association's research staff in the corrosion section for a number of years.[14, 15, 16, 17, 18, 19] This work began with a study of the stress corrosion of the aluminium—7% magnesium alloy. The effects of heat treatments which might be accidentally applied in service and increase the susceptibility to stress corrosion by precipitation of the β (Mg_2Al_3) phase in certain ways were investigated, together with the effect of corrosive environment, surface finish and other relevant factors. This work led to the development of a theory of the mechanism of intercrystalline stress corrosion in this alloy, and to an extension of the work to other aluminium alloys and to magnesium alloys. The general problem of selective corrosion at grain boundaries and intercrystalline weakness under creep and other conditions of stressing continues as an item in the current research programme.

General Metallurgy

The study of reactions involving gas/metal equilibria is a large part of this section's activities. For instance, a paper on the equilibrium between oxygen and phosphorus in molten copper is shortly to be published, and other work is in hand on the reaction between steam and molten aluminium alloys containing reactive elements such as magnesium. In this case the reaction which occurs when the molten metal is poured into a sand mould gives rise to undesirable gas porosity in the sand casting of some of these high strength alloys. The development of methods for complete suppression of this reaction in large castings awaits the results of this fundamental research.

Copper losses in slags in copper smelting operations amount to only a very small percentage of the copper treated, but the total tonnage is large. To assist members of the Association engaged in large-scale copper smelting enterprises in the Commonwealth, research is in hand to find out in what form copper is lost in slags. The solubility of copper in typical slags in contact with molten copper or molten copper sulphide mattes under different gas atmospheres is therefore being studied.

The oxidation of copper on exposure to the atmosphere at various temperatures has been investigated.[20, 21, 22] It has been possible to explain the marked difference in the adherence of scales on phosphorus-containing and phosphorus-free coppers in terms of the differences in the mechanical properties of the scales. The work on the oxidation of copper is being continued at Durham University, under the direction of Professor Preece, and special attention is being paid to the behaviour of copper alloys in atmospheres typical of the exhaust gases of gas turbines. This work is related to investigations in progress in the Mechanical Testing Section of the B.N.F.M.R.A. on the creep and fatigue properties of copper alloys which may be used in the construction of heat exchangers for land or marine gas turbine power units. The creep and fatigue testing equipment described in this Journal a year ago is being used in this research.[23]

9 Bailey, G. L., "Copper-Nickel-Iron Alloys Resistant to Sea-Water Corrosion," *J. Inst. Metals*, July, 1951, **79**, 243–292.
10 Gilbert, P. T. and May, R., "Materials for Use in Ships' Condensers and Other Seawater-Carrying Systems," *Trans. Inst. Marine Eng.*, Aug., 1950, **72**, 291–294.
11 Slater, I. G., Kenworthy, L. and May, R., "Corrosion and Related Problems in Seawater Cooling and Pipe Systems in H.M. Ships," *J. Inst. Metals*, June, 1950, **77**, 309–330.
12 May, R. and Stacpoole, R. W. de Vere, "The Jet Impingement Apparatus for the Assessment of Corrosion by Moving Seawater," *J. Inst. Metals*, June, 1950, **77**, 331–344.
13 Rogers, T. Howard, "A Method for Assessing the Relative Corrosion Behaviour of Different Sea-Waters," *J. Inst. Metals*, Feb., 1950, **76**, 597–611.
14 Perryman, E. C. W. and Hadden, S. E., "Stress-Corrosion of Aluminium—7% Magnesium Alloy," *J. Inst. Metals*, May, 1950, **77**, 207–235.
15 Gilbert, P. T. and Hadden, S. E., "A Theory of the Mechanism of Stress-Corrosion in Aluminium—7% Magnesium Alloys," *J. Inst. Metals*, May, 1950, **77**, 237–261.
16 Hadden, S. E. and Perryman, E. C. W., "Stress Corrosion of Aluminium—7% Magnesium Alloys: Effect of Surface Finish," *Metallurgia*, Dec., 1950, **42**, 392–396.
17 Perryman, E. C. W. and Brook, G. B., "Mechanism of Precipitation in Aluminium-Magnesium Alloys," *J. Inst. Metals*, Mar., 1951, **79**, 19–34.
18 Perryman, E. C. W. and Blade, J. C., "Relationship between the Ageing and Stress Corrosion Properties of Aluminium-Zinc Alloys," *J. Inst. Metals*, May, 1950, **77**, 263–286.
19 Perryman, E. C. W., "Stress-Corrosion of Magnesium Alloys," *J. Inst. Metals*, Feb., 1951, **78**, 621–642.
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21 Tylecote, R. F., "The Oxidation of Copper at 350°–900° C. in Air," *J. Inst. Metals*, **78**, 327–350.
22 Tylecote, R. F., "The Adherence of Oxide Scales on Copper," *J. Inst. Metals*, Dec., 1950, **78**, 301–326.
23 McKeown, J. "The British Non-Ferrous Metals Research Association: Creep and Fatigue Testing Equipment in the Laboratories." *Metallurgia*, Sept., 1950, **42**, 189–196.

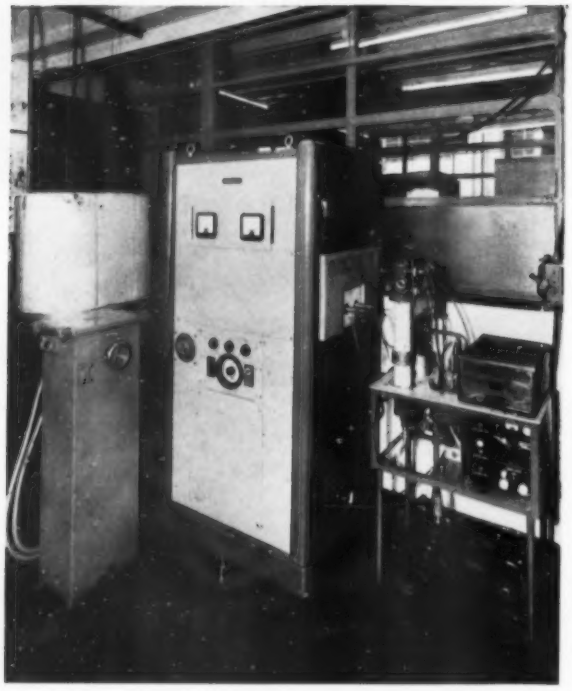

Fig. 4.—Small high-frequency, high-vacuum melting furnace capable of melting and casting approximately 2 lb. of copper-base alloy, while maintaining the pressure below ½ micron. The apparatus utilises the Association's portable 7 kW. output high-frequency generator and a pumping set incorporating a 2-in. mercury vapour diffusion pump and liquid air trap. It is at present used for the production of alloys of high purity for research on the properties of grain boundaries.

Provision of facilities for routine metallographic examination for the whole of the Association's laboratories is one of the functions of this section and a general review of the different techniques in use, including polishing with diamond dust, new etching techniques for use with aluminium alloys, the use of polarised light, phase contrast microscopy, and microhardness testing, has just been published.[24]

Metal Coating

An international conference held in Copenhagen last year was made the opportunity for reviewing the work done by the Research Association for the galvanizing industry during the past 20 years.[25] Current work is not solely concerned with the action on zinc economy already discussed. The attack of the fluxes used in the galvanizing operation on the steel being coated has been shown by industrial trials to be of considerable importance, controlling the amount of dross made under operating conditions. This reaction requires further study before conditions for galvanizing with a minimum dross production can be fully specified. The Association has recently been granted patent protection[26] for a new process for the lead coating of steel and copper using substantially pure lead. This process, which should permit considerable economies, owing to the avoidance of the expensive metal tin, appears to be particularly well suited for certain dip soldering operations and the mechanical properties of joints made in this way are under investigation.

Research on a different aspect of metal coating is undertaken for the electroplating industry. The increasing support received by the B.N.F.M.R.A. for research on electroplating and allied subjects has been recognised by the establishment of an Industry Committee to advise on research policy for this section of our membership. Much effort is being concentrated on the investigation of the quality of nickel electrodeposits which has already been mentioned, but in addition, a study is being made of electrodeposition on aluminium and aluminium alloys, in view of the increasing part which light alloys are likely to play in the future in providing material for decorative uses. The sodium zincate process, in which a preliminary coating of zinc is applied to the aluminium surface by chemical replacement before electroplating commences, has already received considerable attention.[27] The performance of subsequent electrodeposits has been shown to be greatly influenced by the form of the zinc deposit and this in turn by the composition of the sodium zincate solution. The work has enabled composition ranges to be recommended which give the maximum adhesion of subsequent electrodeposits.

Information and Liaison Services

This article has concentrated on the work of the Research Department; it must not, however, be forgotten that important services to members are given by the Information Department and Library, and by the Liaison and Technical Service Department, and these continue to be much in demand. In 1950, 8,847 loans were made from the Library externally to members, Government Departments, etc., and an almost equal number internally to the staff of the Association. During the same year technical enquiries were received from 49% of the membership.

The work of the Liaison Department includes the provision of Development Reports, in which the researches of the Association are interpreted in the light of works experience or special investigations, so as to facilitate their application by members in their own plants. In addition, mention should be made of the *B.N.F. Review* (formerly the *B.N.F. Bulletin Research Supplement*). This publication was instituted a few years ago for the special purpose of providing concise and informative reviews of research reports, in order to help members to acquire rapidly and easily a knowledge of the work in progress and to select any desired full reports for more detailed study. The production of these reviews involves a great deal of work on the part of the Liaison Department and senior members of the Association's staff, but there is growing evidence that this effort to make the research results more easily assimilated is appreciated by the membership, and that the *B.N.F. Review* (which is confidential to members) is widely and carefully read.

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25 Hall, W. L. and Fagg, D. N., "Twenty Years of Research for the Galvanizing Industry," *International Conference on Hot-Dip Galvanizing held at Copenhagen July 17th to 21st*, 1951, pp. 14–29.

26 B.N.F.M.R.A., Bailey, G. L. J. and Watkins, H. C., *Brit. Pat. Spec.* 657,025 (Appn. Nov. 10th, 1947).

27 Bailey, G. L. J., "Electrodeposition on Aluminium: A Study of the Zincate Process," *J. Electrodepositors' Tech. Soc.*, 1951, **27**, Advance Paper No. 10, 22pp.

The British Welding Research Association

By K. Winterton, Ph.D., B.Sc.

Continued advances are being made in investigations of a metallurgical nature into the problems arising in the welding of various metals, and at the same time considerable attention is being given to the engineering aspects of welded construction. This latter activity will be greatly assisted by the completion of the new fatigue laboratories at Abington.

PROGRESS during the year has involved the extension and development of the several well-established researches already proceeding in the Engineering and Metallurgical Departments of the Association. Some entirely new work has been taken on, and perhaps the most important is a programme of work on oxygen cutting. These additional activities have imposed an increasing demand for laboratory space at the London premises (shown in Fig. 1), which are the headquarters of the Association. Additional space has been allocated for the metallurgical laboratories by means of internal reorganisation.

At the Abington Research Station a new permanent laboratory is being built. Here will be housed a 100-ton vertical Losenhausen fatigue machine and other apparatus for researches on fatigue strength. When this laboratory is finished it should provide unique facilities for the testing of full-scale structures, and should lead ultimately to great economies in the use of steel in structural design.

To speed the advance and to extend the range of the various researches, a good deal of new standard equipment has been acquired during the year. To give a few instances, a high-speed strip chart temperature recorder has made very much easier and quicker investigations involving cooling rate in the development of weldable structural steels of high strength. Other special purpose equipment includes a Kentron microhardness tester and a high-temperature furnace for homogenisation and other high-temperature operations.

On the resistance welding side, electronic instruments and a comprehensive range of control gear are now available.

The Liaison and Development Department continues to provide a most useful service to industry, and during the present year about 500 enquiries have been dealt with and well over 300 visits made to various firms in consequence. To meet the increasing demands of the service, the library facilities have been extended, and on a smaller scale a library of films and lantern slides has been formed.

A summer school for welding was arranged at Ashorne Hill in May of this year. This was a new responsibility for the Association, but proved to be extremely popular and was very well attended. Most of the leading authorities in the field participated, and in all 63 lectures were delivered. Discussions, demonstrations and film displays helped to make the nine-day course very comprehensive. In view of the success of this venture it is very likely that it will become an annual feature.

Metallurgical Research

Constitution of Mild Steel Weld Metal

The problem of hot cracking continues to receive the main attention in this field. A new double fillet hot cracking test has been developed, which is now available with several gradations in severity, and which is much more severe than any previous known test. More important than this, the new test is reasonably reproducible, though remaining fairly simple in operation. It is hoped soon that the test will be given a widespread trial in industry. This empirical work, though serving a useful and important purpose, is limited in its scope, and complementary work is proceeding to determine, if possible, the fundamental causes of hot cracking. Experiments have shown, for instance, that the atmospheric gases oxygen and nitrogen do not play an important part, but the latest work gives indications that hydrogen may have some influence, and apparatus is being built to make tensile tests at high temperatures in an atmosphere of hydrogen. For this work, and for the work which is next described on alloy steels, it is necessary to compare electrodes from the point of view of the amount of hydrogen evolved from the deposited weld metal. A test in progress is shown in Fig. 2.

Fig. 1.—The Association's London headquarters.

Higher Strength Weldable Structural Steel

Arising out of investigations of the weldability of a series of about 30 experimental low alloy steels of the nickel-chromium-molybdenum type, a good deal of attention has been focused on two selected steels of promising weldability. The next step in this investiga-

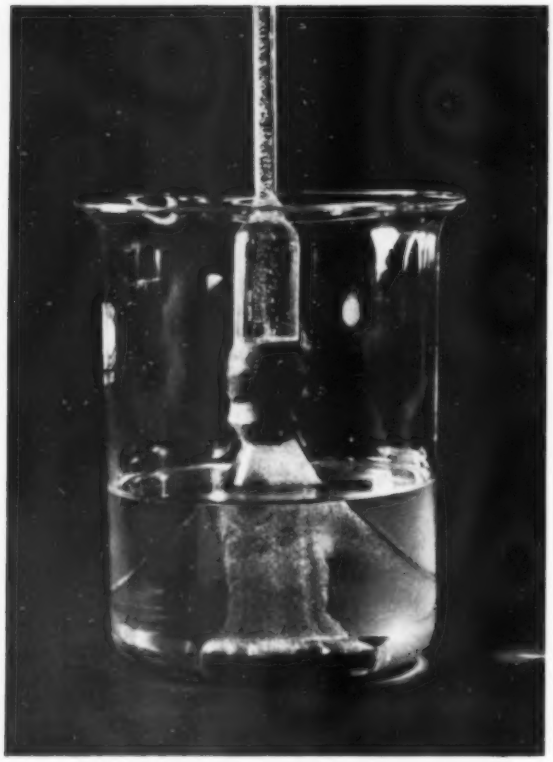


Fig. 2.—Measurement of hydrogen evolution from deposited weld metal.

tion will be to test a further series of steels with compositions varying around these two preferred analyses. The most important single conclusion arising from the work is the overriding influence of rate of cooling on the incidence of cracking in the hardened zone. It is now possible to make a simple thermal analysis of any given welded joint in order to establish the correct welding procedure—choice of electrode, size of deposit, etc. During the course of these investigations a great number of different weldability tests has been employed, but the conclusions of the work have made it necessary to recommend a new test, with graded thermal severity, which is more soundly based and which appears to give reliable and reproducible results. This test has already received considerable recognition, and can be used either for the classification of electrodes or alloy steels from the point of view of their tendency towards hardened zone cracking. A series of test assemblies is used for this purpose, as shown in Fig. 3.

Fusion Welding of Light Alloys

Traces of sodium picked up from the electrode coating have been shown to have a harmful influence in the metal arc welding of an aluminium alloy (5% magnesium). The new inert gas-shielded metal arc process, first developed by the Air Reduction Company in the U.S.A., has been further investigated, and plans are going ahead to cover not only the aluminium alloys but also some of the new magnesium alloys important in the aircraft industry. The apparatus which has been developed at B.W.R.A. for this purpose is shown assembled in Fig. 4, and has many novel features over the American counterpart. A torch has also been developed for use with 600-amp. argon-arc welding equipment, and this has made possible some useful developments in the welding of heavy section aluminium plate. Some important discoveries with regard to correct phasing and also the reduction of open-circuit voltage have emerged from work carried out in collaboration with the British Electrical and Allied Industries Research Association, involving the oscillographic analysis of electrical phenomena in the A.C. argon-arc process. Ultimately this will make possible an improvement in the power factor and safety of commercial welding transformers.

Engineering and Other Researches

Load Carrying Capacity of Frame Structures

The great saving in weight made possible by using plastic design is attracting much attention, and valuable practical experience is being gained from the erection of the new fatigue laboratories at Abington, where the new plastic design principle is being used for the first time.

In the design of full-scale Portal frames, some useful information is now available from the experimental and theoretical work on the bending of simply supported rolled steel joists: the necessary calculating methods have been given a wide circulation. Experiments have been made on the loading of structural members beyond the yield point, and these include a series of small scale I-section beams tested under symmetrical two-point loading, account being taken of the effect of end conditions. Studies of the behaviour of stanchions loaded to collapse have shown that in some cases failure may occur about the minor axis before the full plastic moment about the major axis is attained. A tentative theoretical treatment has been developed for the lateral instability of stanchions bent about the major axis in

Fig. 3.—Weldability-test assemblies.

either single or double curvature, and this is being further tested by experiment.

Behaviour of Welded Structures under Dynamic Loading

A test rig for carrying out repeated bend tests on 6-in. pipe specimens is shown in Fig. 5. Later on, it is hoped to test the effect of weld faults on the fatigue endurance of such pipes. In the fatigue testing of welded joints in pressure pipe lines, some values have already been determined for plain pipes. Another important investigation is designed to assess the influence of residual stresses on fatigue endurance. To do this a new method of stress measurement has been developed which uses an electrical inductance type strain gauge (Fig. 6) to measure the elastic recovery between gauge marks on the surface of a thermally stressed specimen after cutting into small elements. Several welded structures have been tested to failure, using push-pull fatigue tests, to determine the fatigue behaviour of fillet-welded connections, the welds being subjected to alternating shear loads with equal elements of tension and compression.

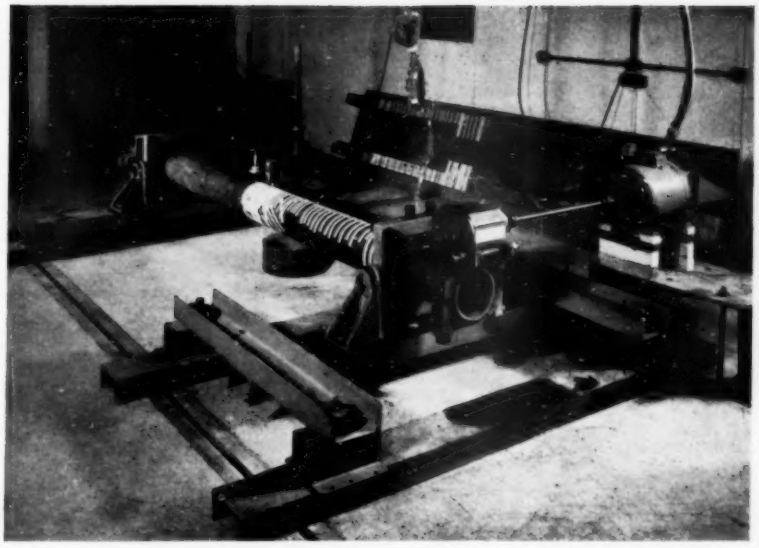


Fig. 5.—Apparatus for repeated bend tests on 6-in. pipe specimens.

Fig. 4.—B.W.R.A. inert gas shielded arc welding apparatus.

Testing of Welded Pipes and Pressure Vessels

The new pulsating pressure plant has been used to test superheater elements, lengths of straight pipe and also a welded T-piece of 6-in. diameter pipe. Pipe bend specimens of large diameter have been tested in both mild steel and stainless steel under external forces reducing the radius of curvature. Reports are also available dealing with the earlier experiments of the same type on short radius pipe bends. A full-scale pressure vessel has been tested under static internal pressure of up to 700 lb./sq. in. This vessel was fitted with three unreinforced branches of different wall thickness, and 428 electric resistance strain gauges were fitted on the inside and outside surfaces of the vessel. Diagrams have been prepared of the strain distribution, from which the computation of stresses can be made at all important measuring points. The new pulsating pressure plant has been found to work satisfactorily in the fatigue testing of both vessels and pipe specimens. "Stress probing" is a new method which has been developed to obtain rapid stress surveys on vessels subjected to pulsating pressure. A normal Huggenberger extensometer is modified for this purpose by adding a pistol grip handle, so that it can be pressed on to the surface of the specimen; the amplitude of the pointer movement gives a measure of the strain. The main use of this method is to determine fairly quickly the best places for mounting the more accurate resistance strain gauges.

Resistance Welding

Triple projection welding has been found to be very satisfactory for 16 S.W.G. low carbon steel. A projection welding head for making three projections in triangular formation at a 2 in. pitch is shown in Fig. 7. Experimental stud welds made between $\frac{5}{16}$ in. shank diameter studs and 12 S.W.G. sheet have been tested by torsion, tension and impact torsion, and from the results a standard design for the stud has been recommended. The range of this work is being extended to cover stud design for two other shank sizes and for a number of

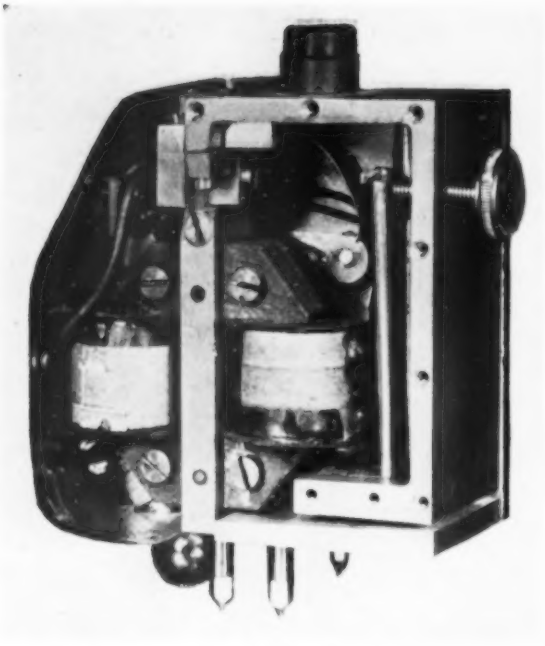


Fig. 6.—Electrical inductance type strain gauge.

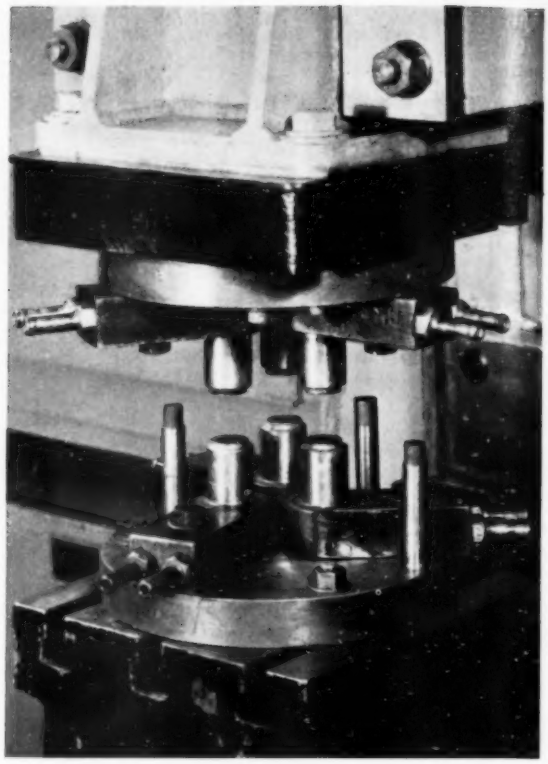


Fig. 7.—Projection welding head for making three projections in triangular formation at 2-in. pitch.

different sheet thicknesses. The optimum conditions for spot welding mild steel are being determined for a wider range of gauge thickness than heretofore. Steel quality is one of the variables which are being considered; for instance, five grades of low carbon steel of 18 S.W.G. thickness are being tested, and the work will include an investigation of the effect of ageing after welding on the mechanical properties. Further tests have also been made on light alloy box-section members. By concentrating on improving the strength consistency, the static strength of the welded boxes is now superior by about 15% to that of the strongest riveted boxes. No firm conclusion has been drawn with regard to their relative life under fatigue conditions, but so far, under the particular test conditions used, there seems to be little to choose between the riveted and spot-welded specimens.

Oxygen Cutting

The Association's interest in oxygen cutting has been stimulated by the lack of fundamental knowledge of the mechanism of the process. Theoretical investigations have, however, shown such correspondence with practical experience as to indicate that the correct method of approach is being used, and experimental work of a simplified nature has commenced.

The first experiments were made by burning steel tubes through which oxygen and air were blown, but difficulties were encountered in that combustion could not be sustained for more than about one minute. A more satisfactory procedure has been found to be to use the gas flow directed perpendicularly across the end of a rotating bar. This method is proving susceptible to mathematical analysis, and once the procedure is established various factors, such as oxygen purity, can be investigated.

Photographic Society Exhibition

The Royal Photographic Society's 96th Annual Exhibition was opened by the Rt. Hon. The Lord Brabazon of Tara, M.C., Hon. F.R.P.S., on Thursday, September 13th, 1951, in the Society's House, 16, Princes Gate, S.W.7, close to the Albert Hall. It will remain open to the public without charge until Sunday, October 14th, 1951, from 10 a.m. to 8 p.m. daily (Saturdays 10 to 5-30, Sundays 2-30 to 5-30).

This is recognised as the premier photographic exhibition of the world, comprising as it does all types of photography. Over 5,000 entries were received, of which 908 have been accepted. Pictorial photography undoubtedly provides the main interest but there are excellent examples of scientific, nature, stereoscopic and record photography, in monochrome and colour. There are 14 sections of the Exhibition and the voluntary services of 51 selectors were required.

In the Society's Annual Exhibition the selectors aim at showing work which provides a fair cross-section of contemporary photography, as shown by the material which is submitted for consideration. The Society exists for the development of the science and art of photography and this purpose it endeavours to pursue quite objectively.

After the London display the whole of the Exhibition will be transferred to Aberdeen, where it will be shown in the City Art Gallery from Saturday, November 3rd, to Saturday, November 24th, 1951.

The Research and Development Division of the British Steel Founders' Association

By J. F. B. Jackson, B.Sc., A.R.I.C., F.I.M.
Director of Research.

The Research and Development Division of the British Steel Founders' Association is one of the youngest of the research organisations in the metallurgical field. A brief outline of its organisation is presented and particular reference is made to three of the many fields of research in which it is already engaged.

THE Research and Development Division of the British Steel Founders' Association, contrary, perhaps, to the impression given by its present title, is an autonomous research organisation, is independently financed, and is subject only to the authority of its own governing council. It has its administrative headquarters in Sheffield. The Division has the wholehearted support of the industry it serves, and, since the disbandment of the Steel Castings Division of the British Iron and Steel Research Association earlier this year, it is the sole authority responsible for collective research within the steel founding industry of this country.

On its formation in 1949, it was stated that its policy would at all times be such as to ensure adequate attention being paid to research work of a technological and practical nature. It was proclaimed as a prime purpose of the Division that it should enable the results of fundamental research to be applied by the industry and that it should, through its permanent staff, bridge the gap between the extremes of theory and practice.

That this declared policy has been rigorously followed has been amply demonstrated in many ways since the Division's inception. A balance between science and technology is evident in its relatively small but experienced and carefully appointed permanent staff, in its committee structure and of course in its research programme.

Committee Structure

In common with similar organisations the administrative policy of the Division is determined by its annually appointed council, to which body of course both the Director and Secretary are responsible.

For purposes of internal organisation, the activities of the Division are regarded as falling primarily into four general fields, i.e., foundry practice, plant engineering, metallurgy and quality, steelmaking and heat treatment, and as will be seen from the accompanying chart four Main Technical Standing Committees corresponding to these fields have been appointed.

The Standing Committees are composed of senior executives and officials of member firms and include research and works metallurgists, chief inspectors, foundry and works managers, melting shop managers, and others of similar standing. From this it will be seen that these four committees have the necessary breadth of experience and knowledge of steel castings technology to ensure that the work upon which the Division is engaged, whether of a research or a development nature, is so directed that it is in keeping with the requirements of the industry. No less important, the Standing Committees enable member firms to be prepared in advance, through knowledge of the work that is in hand, to receive and assimilate the results that are obtained.

In addition to the Standing Committees, a number of Specialist Panels have been formed. As their name implies, it is the function of these Panels to deal with specific fields of importance to the industry and, in particular, to comment upon and criticise the longer term fundamental research work which is being conducted by the Division, either in the Universities or elsewhere.

The Panels are each composed of leading authorities, drawn not only from the industry but also from the Universities, from other kindred research associations, government institutions, and in certain cases from organisations in other industries.

Fig. 1 indicates the extent to which such Panels have been formed to date, and it is also evident that provision has been made for the appointment of further Panels as necessity arises. As the diagram shows, the Specialist Panels are independent of the Main Technical Standing Committees and they are in effect autonomous, working directly with and advising the permanent staff of the Division.

The Main Technical Committees and Specialist Panels

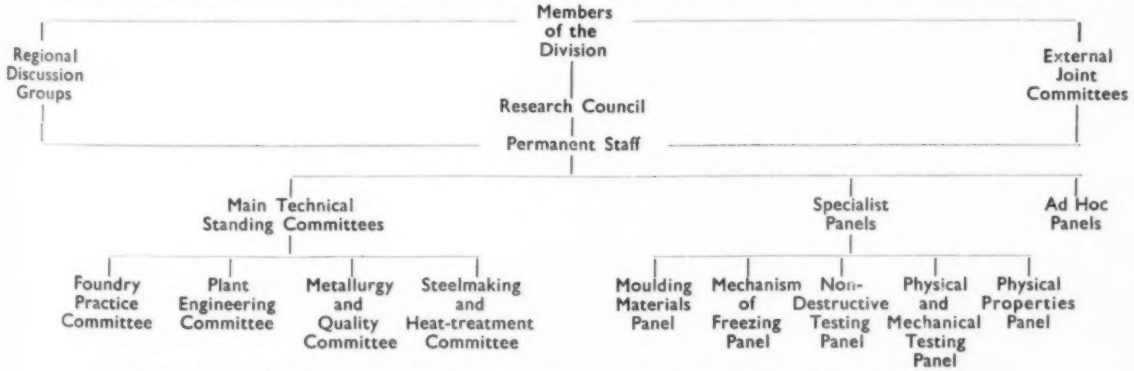


Fig. 1.—Committee Structure of the Research and Development Division of the B.S.F.A.

have, according to their individual terms of reference, absorbed the responsibilities of the various committees previously operated by the Steel Castings Division of the British Iron and Steel Research Association. In this way it has been found possible to ensure that any projects which the latter Association had in hand at the time that its Steel Castings Division was disbanded, have been continued.

From time to time it has been found desirable to appoint certain advisory panels on an *ad hoc* basis to deal with particular problems that have arisen, such panels being disbanded immediately upon the completion of their set task. In this way it has been possible to avoid the building up of an excessively large or unwieldy committee structure, a policy which it is intended shall be continued for the future.

Mechanism of Freezing

An understanding of the freezing mechanism of steel is clearly of vital importance not only to the general theory of the casting process but also in relation, ultimately, to the quality of castings which the industry produces, and to economy and productivity in manufacture. It can, with good reason, be said that even to-day on the mechanism of freezing within one of the simplest forms of steel casting known, i.e., the steel ingot, there is still a great deal to be learnt and as most steel castings may well be regarded as involving a complex series of ingot systems, the magnitude of the problem is evident. Having in mind the importance of research in this field and the fact that any work instituted in relation to it must necessarily be of a very long term character, research projects were ponsored at an early date at the Universities of Cambridge, Durham and Swansea. To these has been added a further research project which previously had been put in hand at the Royal School of Mines by the British Iron and Steel Research Association. Thus there are at this date four long-term fundamental research projects in hand, each dealing with specified aspects of the problem and co-ordinated through the Division's permanent staff and through its Mechanism of Freezing Panel.

Mould Refractories

In this obviously important field very considerable scope for research and development is recognised, and the Division, apart from its close association with the Refractories Department of Sheffield University where a number of major projects are in hand, has further investigations proceeding in Cambridge.

In Sheffield, investigations are being made towards a clearer understanding of the bonding properties of clays, with special reference to their performance at high temperature, and in relation to the plasticity of moulding sands, a property which is as yet not fully understood but which nevertheless is vital in its influence upon ordinary moulding practice.

In Cambridge, a study is being made of the heat transfer characteristics of commonly used moulding materials and of the factors which influence them. This work which is intended to establish essential basic data is also linked with the researches previously discussed in relation to the mechanism of freezing.

Also in Cambridge, the technique successfully developed by T. P. Hoar and D. V. Atterton (*Journal of the Iron and Steel Institute*, September, 1950), is being applied to determine precisely the factors controlling moulding sand penetration by molten steel, a field of investigation which has been entered by many research workers in the past, but so far without a satisfactory answer being obtained. The problem of metal penetration of the mould face is, of course, largely influenced by the high temperatures common to steel foundry pouring practice, and it can be regarded as one of the major unsolved, or only partially solved, problems with which steelfounders are faced. Not only are the consequences of metal penetration far-reaching in terms of productivity—i.e., in the consumption of effort in the dressing shops in the removal of adhering metal-sand agglomerate from the surface of steel castings, but also in relation to pollution of the atmosphere with siliceous dust. The Cambridge research in question, therefore, has a particular importance to the industry and to the health of the people that work in it.

In addition to the laboratory facilities and specialist staff under Dr. J. White at Sheffield University which are available to the Division, it also has the benefit of the advice of its Moulding Materials Panel, under the chairmanship of Dr. J. R. Rait, in respect of its work upon steel foundry moulding refractories.

Steel Foundry Dust

The complex but vital problem of atmospheric dust reduction and control in steel foundries is receiving unremitting attention from the Division, this ranging from long-term fundamental researches in the Universities to field work of a practical type. The latter has included statistical surveys of the atmospheric conditions associated with each stage in the steel founding process.

At Reading University bio-chemical investigations on an increased scale have been sponsored in order to determine the relative toxicity of various forms of siliceous dust, with the ultimate aim of isolating and identifying any dangerous constituent or constituents of dust that are particularly active in giving rise to lung changes.

The work which the Division has in hand in Cambridge on sand penetration by molten steel has already been mentioned. This has, of course, an important bearing upon the prevention of dust formation. In London, more recently, a development has been supported which it is anticipated will lead towards the evolution of an ultra-rapid method for the counting of dust particles and for the determination of their size distribution. Those who are acquainted with the technique of atmospheric dust sampling and analysis will readily appreciate the far-reaching contribution to the industry's researches to be given by apparatus which will render such continuous assessment practicable. The serious limitations inherent in apparatus so far devised for this intended purpose will, it is confidently believed, be eliminated by the conclusion of this development.

Although it is not within the scope of this statement to describe in detail the widespread effort that is being made towards the reduction and ultimate elimination of the dust hazard in steel foundries, it can be said that no new process, or possible modification to existing processes, which appears to have potentialities is consciously overlooked.

While the prevention of dust formation at each stage in the steel casting process must always be the objective, in the meantime equal attention is being paid towards the provision of measures which will satisfactorily control such dust as is formed and provide the necessary protection from it.

The work of the Division and of the British Steel Founders' Association in this field is closely co-ordinated with that of H.M. Inspectorate of Factories, and there is appropriate liaison with other authorities having similar problems before them, such as the Safety in Mines Research Establishment of the Ministry of Fuel and Power.

Other Activities

The Division has at this date 12 long-term researches in hand at the various Universities, some of which have been referred to in this article. In addition, its current programme includes, of course, many projects which may properly be regarded as coming under the heading of process developments.

Its Library and Information Service is available primarily for assistance directly to its member firms, but an increasing flow of inquiries from users of steel castings and from other research organisations has, within certain limits, extended the scope of this service.

Contact is maintained with parallel associations concerned with foundry research and metallurgy, notably the British Cast Iron Research Association, the British Non-Ferrous Metals Research Association, the Institute of British Foundrymen, and the Steel Founders' Society of America. In the case of the last-named, a basis for the exchange of research findings has been agreed and has now been in operation since mid-1950. On the Continent similar good relations exist with the Jernkontorets, and Metallografiska Institutet, Sweden and the Centre Technique des Industries de la Fonderie, France.

In matters of common interest, such as steelmaking, furnace refractories and pyrometry, an arrangement exists between the Division and the British Iron and Steel Research Association for the interchange of information between their respective staffs and of published reports.

In common with certain other research organisations of more recent origin, the Division does not plan the building and equipment of extensive research laboratories of its own. The view is held that, in the interests of economy of scientific manpower as well as of finance, the better policy is to locate each research project according to the demands peculiar to it, either with the industrial or the University laboratory best suited in all respects to undertake the work.

It is felt equally firmly that, apart from any question of economy, such a procedure, with its inherent flexibility and freedom of choice, is the more likely to be effective in producing results.

Pursuance of this general policy has not, of course, precluded the Division from providing itself with suitable equipment or access to plant where the demand is constant, i.e., in respect of certain laboratory services and of experimental steel melting and casting facilities.

The Division has, during its formative period, received ready help and advice whenever this has been sought from any one of its sister research organisations and, particularly, from the Department of Scientific and Industrial Research.

Mechanical Engineering Research

First Report on Progress

THE Mechanical Engineering Research Board was appointed in 1946 and its first meeting was held in May, 1947. The headquarters of the Mechanical Engineering Research Organisation, D.S.I.R., for which it is responsible were then set up in London. Since that time, M.E.R.O. has moved to East Kilbride in Scotland and the building of extensive workshops and laboratories is under way there. The first report* which M.E.R.O. has issued on its work gives details of the origin of the research station, the scope for its work and the progress which has been achieved so far. Much of the work up to now has been carried out at the National Physical Laboratory, while some of it has been done at temporary premises near East Kilbride.

Since the report was prepared the first buildings completed at East Kilbride are the workshop, the boiler house, and the main part of the Properties of Materials laboratory. So that the most rapid progress can be made with research, the laboratory will be used at first as a general purposes building available for experimental work on materials, mechanics of solids, fluid flow, heat transfer and mechanics of formation.

Unification of Screw Threads.—An important branch of the work carried out by M.E.R.O. has been that on screw threads, particularly significant because of the present armaments programme. The need for information on the relative strengths of new and existing forms has been increased because of the recent agreement with Canada and the U.S.A. on a common form of screw thread. Tests to investigate the influence of nut height showed that no decrease in fatigue strength occurred until the nut height was less than three-quarters of the stud diameter. Extensive tests have been done on the strength of $\frac{3}{4}$ in. diameter 10 t.p.i. threads and further tests are in progress on $\frac{3}{8}$ in. diameter 20 t.p.i. threads.

Effect of Size on Fatigue Strength.—Experimental work on fatigue of metals is usually carried out on specimens of less than $\frac{1}{2}$ in. diameter, but it is not possible to predict what will happen to larger components, under repeated loadings, from tests on such small specimens. A beginning has been made on the testing of larger pieces, particularly of materials used in aircraft construction. Tests carried out on specimens of up to 12 in. wide of high strength aluminium alloy and mild steel sheet have shown that a $\frac{1}{16}$ in. diameter central drilled hole reduces the fatigue strength of the sheet to a much smaller extent than does a $\frac{3}{4}$ in. diameter hole. Similar work has been begun on a high strength magnesium alloy. Riveted and welded joints in this material are also being tested. Improved machines for testing larger specimens and complete components are being developed.

Properties of Metals at High Temperatures.—Work on creep, the gradual increase in length of hot metals under load, is being tackled in two ways. The long term research is intended to achieve a greater understanding

* "Mechanical Engineering Research, 1947–1950," published for the Department of Scientific and Industrial Research by His Majesty's Stationery Office, price 2s. 6d. (65 cents U.S.A.); by post 2s. 9d.

of the underlying reasons for creep and the short term work to provide design data for such applications as steam and gas turbines, the latter work being vitally important to the present large programme of power station building for the British Electricity Authority.

The behaviour of typical steam plant steels under peak load and temperature conditions is being studied by examining the effect of small periodic increases of stress and temperature on their creep characteristics. Fluctuating stress tests have been carried out on 0·26% carbon steel at 400° C. and during the tests measurements of creep were taken. A theoretical estimate of this creep agreed with the experimental results.

Fretting Corrosion.—When the surfaces of two components of a machine fit closely together and there is only small movement between them the surfaces may be damaged by "fretting corrosion." This causes roughness of the surfaces from which fatigue cracks can develop and lead to failure of one or other of the components. Previous work had indicated that the oxide layer on the surface of the metal was mainly responsible for fretting corrosion. Tests using gold which does not oxidise easily also resulted in severe damage to the specimens. This led to a re-examination of the earlier theories and to the conclusion that the phenomenon is primarily dependent on metallic contact, the effect being modified by the nature of any oxide film formed. Nickel or chromium plating of the surfaces produced little improvement, but recent tests on phosphated surfaces have given very encouraging results.

Surface Finish.—For machines to work and last well it has long been known that certain standards of finish must be achieved in their manufacture. Instruments suitable for use in the workshop are being developed so that inspection will show whether the finish is suitable for the job. Certain machine parts, however, are not easily measured because they cannot be spared for the necessary length of time or because they are too big. For such parts the use of the plastic replica method, a kind of "dental impression" is being examined. The replica of the surface made by this means can be taken away and measured in the laboratory with little trouble.

Extra-Departmental Research.—During the growth of the new organization the part being played in the research programme by Universities and Technical Colleges is particularly valuable. There are frequent references in the report to this work. The most important are those to work on the fundamental reasons for fatigue failure of metals at Bristol, fluid flow problems at Cambridge, extrusion at Sheffield, screw thread rolling at Edinburgh and the mechanism of condensation at London.

International Industrial Research Institute

AN international industrial research institute to serve the European economy will be established in Europe this autumn. To be known as Battelle International Institute, the European activity is being established by Battelle Institute, Columbus, Ohio, U.S.A., the world's largest industrial research foundation. According to Battelle Director Clyde Williams, it proposes to serve European industry, on a non-profit basis, through science and technology. Battelle International will establish research investigations in existing research institutes of Europe and in European universities and technical schools. It will also operate its own laboratories on the continent, the exact locations of which will depend upon the outcome of negotiations now in progress.

As with the parent organisation, financial support for these activities will be derived from industrial sponsorship, from endowment, and from income from patents owned by Battelle. It will conduct research in the fields of applied chemistry and physics, metallurgy, fuels, ceramics, electronics, theoretical and applied mechanics, the engineering sciences and agriculture.

John S. Crout, for many years Assistant Director of Battelle, has been named Executive Director of the new institute. In discussing the results of a recent survey of scientific and industrial conditions in Europe made by Mr. Crout, Dr. Williams commented, "The progress of European industry in re-establishing itself amazes us. We are encouraged by the energy with which Europeans are continuing this effort. We share the confidence of Europe that industrial research can accelerate this regeneration. From this we are encouraged to anticipate the growth of our research in Europe to an annual budget in excess of $1,000,000 within three years."

"The accumulated knowledge and experience gained through Battelle's service to American industry can do much to help industry in Europe to increase its productivity, expand its markets and reduce costs," Dr. Williams said. "At the same time, the establishment of research projects in Europe will create increased opportunities for European scientists and engineers to work more effectively in their chosen fields. They will thus contribute more fully to the welfare of their countries. We believe further that the establishment of an international research centre, in which scientists and engineers from all nations may work together and exchange ideas and methods, will do much to promote world peace by encouraging understanding and friendship among technical men of all nations. We look forward to this opportunity to increase our service to mankind throughout the world."

Mr. Crout has helped to pilot Battelle Institute through its period of greatest expansion to become the world's largest independent industrial research laboratory. He joined the executive staff of Battelle in 1941 when he took charge of administering the Institute's programme of research that is financed directly from the Battelle endowment. Later he was placed in charge of all scientific personnel. He also assumed responsibility for the administration of patents held by the Institute. As Assistant Director, he has gained an intimate knowledge of Battelle's policies and how they operate. He is recognised in scientific and industrial research in the United States. Mr. Crout plans to return to Europe in October to undertake the establishment of the new institute.

Battelle Memorial Institute was founded and endowed to serve mankind through the application of science to the problems of industry. Since 1929, at its laboratories in Columbus, Ohio, it has served the industry of America and the continents. It has, currently, a staff of 1,600 scientists, technologists, and their assistants. This year it will conduct an estimated $9,000,000 worth of research.

Joining Porous Metal Parts to other Metals

By H. W. Greenwood*

The joining of porous metal parts, made by powder metallurgy, to similar parts and to non-porous metals, calls for the modification of accepted methods of joining. An account is given of a number of methods which have been used over a wide field, and reference is made to the conditions under which they have been found useful.

THE increasing use of parts made by powder metallurgy, and the building up of composites from single pressings, as well as the necessity of attaching porous parts to non-porous metals, have provided many problems. Although very few of them have remained unsolved, not only do the methods used vary very much, but accounts of them are widely scattered in technical literature and so are troublesome to find. The present article makes no pretence at completeness, but does offer a number of methods which have been used over a wide field, with some notes on the conditions under which they have been found useful.

Generally speaking, all the commoner processes of joining metals can be applied to the products of powder metallurgy with certain reservations, but the choice of the process which will give the best results will naturally be dependent on the nature of the materials to be joined, and the purpose for which they are to be used. The various methods will be described generally in the order of ease of application, and one of the simplest and most natural procedures with the products of powder metallurgy is that of simple sintering of one part to another.

Direct Sintering of Porous Part to Porous Part or to Non-porous Metal

This procedure can be applied to parts of similar metals, or produced from powders of similar metals, and can be used either for direct joining or for coating as a preparation for subsequent brazing. Direct sintering has been used to join porous metal produced by direct sintering *in situ* to metal channels used as supports for the porous material which acted as a distributing unit to liquid: the joint was not subject to any appreciable load or stress. The two components consisted of a cupro-nickel sponge, with a small percentage of metallic tin which facilitated sintering, and this was joined by the sintering to a Monel metal trough. In the process, temperature control was both accurate and automatic and results over a protracted period were very satisfactory: the sintering was carried out in a reducing atmosphere. In addition to the particular case just mentioned, simple direct sintering can be used in joining copper to copper or to copper alloys, porous iron to iron or to low carbon steel, and in similar cases where compatible metals are involved. Sintering has also been used to provide coatings for subsequent brazing; for example, steel and parts consisting of aluminium alloys have been brazed by using a sintered layer of copper and iron sandwiched between the two principal components. An interesting variant of such a process is the production of a sintered copper-nickel layer on copper-plated steel strip followed by the impregnating of the porous layer with a low melting point lead-tin-antimony antifriction metal after the sintered layer has been subjected to vacuum to remove air from the porous metal. It will be noted that the cases cited are rather outside what might be called normal joining operations, as each involves the sintering of a powder in contact with another part, and not the joining of compact to compact. In actual practice such combination methods are applied frequently and the choice of just what particular form the operations follow will be dependent upon the nature and function of the resulting composite part. The variants of processes will be cited to provide as wide a choice as possible and to suggest as many alternatives, choosing always some method that has been used, if not for the exact purpose required, then at least for some cognate end.

* Powder Metallurgy Ltd., London.

Brazing

This, perhaps the most widely used joining method for metals, has already been mentioned. It is applicable for a wide range of powder metallurgical products, and not the least of its virtues is that brazed joints are capable of standing high stress and, with judicial choice of material, can also serve in a very wide range of temperatures. When considering particularly the products of powder metallurgy, the porosity of the material will determine whether some pre-treatment to reduce porosity, at the surface, or not is necessary. With very dense parts—i.e., where volume porosity is less than about 6%, it is not necessary to take any particular steps as regards the porosity itself, but it may still be necessary to treat the surface to ensure perfect brazing. Where porosity is much greater than the figure named, the pores are usually interconnected and can be very troublesome. In such cases, steps must be taken to ensure that brazing can be complete and the simplest method of ensuring this is by a process, such as impregnation, which will close the pores over the area to be brazed: this will be discussed shortly. For bright brazing of iron or steel parts it is usual to use copper as brazing metal. It can be used as wire or thin sheet, or even more satisfactorily as a paste of copper powder with a simple dope as a medium or vehicle. Ordinary furnace brazing is not suitable for parts having a high porosity, and even with the usual pressed part or compact with from 10–25% porosity, it will be necessary to impregnate or infiltrate if satisfactory brazing is to be attained. The usual material for impregnating, especially of iron parts, is copper or a copper alloy. Impregnation is decidedly more economical than attaining a much higher density by extra pressing or coining, and it ensures sound brazed joints. The same applies to joints that are to be soldered, whether with soft or hard solders: the impregnation ensures sound bonds and is, in fact, insurance against slight variation in practice causing failures. As an alternative to the normal method of impregnating with a bath of molten metal, or by the melting of a sheet of the impregnating metal on to

the surface to be impregnated, the surface can be sprayed by a metal spray gun such as the Schori "50" Pistol which supplies metal powder under pressure and forces it through an oxy-acetylene or oxy-propane flame. The great advantage of the pistol is the speed and accuracy of the application. It is a simple matter to spray one or a hundred compacts, and to give any desired thickness of coating from 1,000th of an inch upward. The powder pistol will be referred to later when discussing the joining of porous filter plates.

There is one small factor which can play quite an important role in the successful brazing together of parts, and that is attention to the use of easily flowing brazing metal. Pure copper is very much to be preferred for fine work to the usual brazing metals, brasses, etc., because it flows so much more easily. Pure copper powder, whether electrolytic or atomised, is mixed with sufficient simple cellulose dope to make a smooth and somewhat stiff paste and thinly spread over the cleaned surfaces to be brazed. The success of the powder method when using copper led to much experimental work being done with other materials and successful brazing with a wide range of materials has resulted. Silver solders have been widely used, and for joining iron compacts to mild steel, powders containing ferro-manganese and graphite with iron, have proved useful. Mixtures of the same kind, containing some 4·7% manganese, 3·4% carbon and the balance iron, have successfully brazed porous iron compacts to cast iron. The brazing of cemented carbide tool tips is a common, and very well-known, example of the application of brazing to the joining of a powder metallurgy product to steel. It is common practice to use a borax flux in such cases and either copper or bronze as the brazing metal. Silver solders have been used as well as a number of special eutectic alloys of the "eutectic low-temperature welding" alloy type. The brazing of tool tips is a simpler operation than the mounting of drawing or press dies which require the carbide faces that are to be brazed to be highly finished if a high strength braze is to be attained. As there is a notable difference in thermal expansion between cemented carbide and steel, it is not uncommon practice to insert a "cushion" between steel and carbide where large or intricate pieces are involved. Such a cushion can be provided by nickel plating the steel seating that is to receive the carbide inset. Electroplating can also be of service in joining aluminium to nickel, the aluminium being first electroplated with copper.

The increasing interest in refractory materials, and the work that is being done in exploring ceramics and the metallo-ceramic mixtures known as cermets and ceramals, have posed many problems in the cementing and joining of bodies of non-metallic character to metals, and many suggestions have been made of using superficial coatings or giving a metallic coating to such non-metallic materials. Some of them resemble the coating of bright silver that is applied to ceramic insulators to enable metal contacts to be soldered to them. The silver coating in this case is applied in the form of a paint, allowed to dry (which it does very quickly because the vehicle is a volatile solvent) and the painted article is then fired at a comparatively low temperature, resulting in a bright silver deposit which adheres perfectly to the ceramic glaze on the insulators.

Another method which has been patented (B.P.646,377 of 1947) consists in producing rings, thin sheets or other shapes, from mixtures of powdered brazing or solder alloy with the requisite flux and, optionally, a deoxidizer, pressing to the required shape and sintering. Such preformed shapes are used largely in furnace brazing with controlled atmospheres.

Welding

Although welding is not widely used for joining the products of powder metallurgy, there are a few exceptions. Spot and strip welding have both found useful application in joining porous filter sheets and similar products where blocking of pores must be avoided or at least reduced to a minimum. Spot and strip welding confine the blocked-up areas to the actual site of the welds and so no special precautions are required to safeguard the rest of the areas. Direct welding is used in joining refractory metal contacts to supporting materials, but copper brazing is being increasingly used in such circumstances. Projection welding has been employed in the production of sintered wheels to which a gear was attached.

Soldering

Like welding, soldering is being but little used in the joining of parts produced by powder metallurgy. It has found some application, however, in the joining or building-up of a complex assembly from simpler pressed units of brass and copper, and has been used in the fastening of pieces of standard mesh, produced by powder metallurgy, into holders to make sieves. The principal drawback in soldering is that it is rarely possible to apply it without some modification of technique, and the position is complicated by the question of flux. The porous condition of most powder metallurgical productions calls for the use of a non-corrosive flux in rather large quantities, because of the very much larger surface exposed per unit area as compared with the average solid metal. This has led to various devices such as the electro-plating of a surface before soldering—e.g., aluminium with copper before nickel, an extension of a practice common in ordinary electroplating.

Where it is not essential to preserve the surface porosity of compacts they can be impregnated with copper or copper alloy and so provided with a solid surface upon which to solder.

Many useful suggestions as to possible methods of joining up sintered metal to both glass and ceramics may be gathered from the details of methods of soldering glass and ceramics to metal in the electrical industry. A method published recently by G.E.C. illustrates the point. It consists in painting the glass and metal areas with a thin layer of titanium hydride, and placing the requisite amount of solder on the painted area. The parts are then placed in close contact, secured in that position and heated *in vacuo* to about 900° F. At or about this temperature the titanium hydride dissociates, thus causing the solder, which has now melted, to adhere to the titanium painted areas of both glass and metal. A strong tight bond is formed upon cooling. By using soft-metal solders it is possible to subject the glass-metal joints to rapid temperature changes. The method which was first applied to valves is now being used in aircraft ignition systems, and is being suggested for a still wider range of applications.

Finally a word or two more may be said about the application of flame-spraying to the joining of porous metal parts, especially the thin sheets of porous filter materials used in chemical engineering. It is not yet

possible to produce sheets of any considerable area by the usual methods of production, but it has been shown perfectly feasible to join up the sheets by the flame spraying powder process, using the new model Schori "50" pistol. In the case of filters of bronze, the powder used for fastening the sheets together is of the same composition as the sheets themselves. It would seem that the principle will hold good for filter sheets of other metals or alloys—e.g., silver, stainless steel and the like. The process is easily applied and results have been quite satisfactory and may well point to many wider applications, more particularly in view of the fact that the powder pistol can handle practically every metal obtainable in powder form.

Composite Plating

A New Method of Light Alloy Barge Construction

Completed half of the '51 barge being loaded for road transport en route to the Belgian Congo.

T.I. ALUMINIUM, LTD. announce the completion by Thorpe Bros. (Bessborough Works), Ltd., the West Molesey marine and structural engineers, of a new type of barge built in aluminium alloy. Made for OTRACO (the Belgian *Office d'Exploitation des Transports Coloniaux*) for use on the inland waterways of the Congo, the '51 Barge is of interest not only on its own account, but as a pioneer application of a new system of light-alloy construction to which T.I. Aluminium give the name of Composite Plating.

Where traditional construction methods are employed, the relatively higher cost of aluminium alloy has put it, in the past, at a disadvantage in comparison with steel—although it may be argued, even so, that aluminium alloy has compensating advantages in its lightness and strength, while its high resistance to corrosion means reduces maintenance charges. Job for job, however, a vessel made of this material will cost more than one made of steel, unless economies can be introduced into the design and fabrication. It is in effecting these economies that Composite Plating makes its important contribution to marine architecture.

The method (for which patents are now pending) exploits an advantage inherent in aluminium alloys, in that intricate shapes can be extruded to form sections which it would not be possible to roll. With the exception of hatch-covers, the '51 Barge has been built entirely from such extrusions, tailor-made components complete with bulb angles, joggles, etc., which eliminated wastage of material and made further forming unnecessary, so that all remaining work could be undertaken by normal shipyard labour.

The barges have a length of 77 ft.; a beam of 11 ft. 6 in.; a depth to bottom of 4 ft. 6 in.; and carry 60 tons of general cargo in two holds, each 30 ft. long. There are three bulkheads—one amidships and one at each end dividing the holds from the end sections. The barges are double-ended, bow and stern sections being identical, with heavy fenders attached so that they can be pushed if necessary instead of being towed in the usual way.

Each barge is built from two constructional units, consisting of an end section or peak and a midship section 30 ft. long with a bulkhead between: they are being shipped in halves for assembly on arrival. The barges are longitudinally framed—that is to say, the more closely spaced frames run fore and aft. The stringers are 12 in. apart and extend the full length of the barge, but do not run through the bulkheads (i.e., from section to section); where necessary they are connected through the bulkheads by gussets. The transverse frames are spaced 6 ft. apart between the bulkheads. The panels for the bottom, sides, decks and bulkheads are built up by argon-arc welding from special extrusions which consist of a section of what would normally be the shell plating, with an inverted bulb angle or rib integral with it.

The accompanying photograph shows clearly how the panels are built up by welding and riveting the special sections used. These were delivered cut to exact length, thereby eliminating not only a great deal of work by builders, but much waste of material in short ends and offcuts.

All extrusions were made to B.S. 1476, HE 10 WP (T.I.A.44), supplied in the fully heat-treated condition; the alloy also meets the provisional requirements of Lloyds and the Admiralty.

Advantages are four-fold. There is, first, a consider-

able saving on fabrication and forming in the shipyard—the rounded bilges of these craft, for instance, would have required heavy plant and skilled labour had they been made in steel. Secondly, since extrusions can be supplied to exact length, there is a decided saving in material. Thirdly, there is a saving in skilled assembly labour—extrusions produced to close tolerances make lining-up unnecessary, while the most skilled assembly work involved is no more than some simple riveting athwartships to join the fore and aft sections. Fourthly, there is ease in handling, owing to the light weight of the alloy—and this, of course, is a great convenience where road transport is concerned. Add to these four points the intrinsic advantages of resistance to corrosion by marine atmospheres and salt water, and it will be seen that here is an innovation with a future.

High Temperature Protection of Mild Steel by Refractory Facings *

UNPROTECTED mild steel is not suitable for long periods of use in an oxidising atmosphere at temperatures above 500° C. It has hitherto been necessary to resort to heat-resisting steel in cases where a material having the mechanical properties of mild steel is to be used at temperatures much in excess of that figure, and as the cost of heat-resisting steel is about 12 times that of mild steel, and in addition the fabrication of articles from heat-resisting steel is usually considerably more difficult than from mild steel, the resulting article is much more expensive.

During the war a method of up-grading mild steel was developed and used with success for the protection of the mild steel aero-engine exhaust pipes.

The Stoneclad Process

Since the war the latest finish known as "Stoneclad" has been developed by Matthews Refractories, Limited, Paisley Works, Swains Road, London, S.W.17.

It is designed to protect mild steel or cast iron from corrosion at high temperatures and to permit their use in many instances where heat-resisting steel would otherwise be called for; an exception is where the high temperature is accompanied by considerable stress. It consists in carrying, in a boro-silicate matrix, a suspension of insoluble refractories and bonding it to the metal surface by fusion at about 800° C.

The treatment may be a single homogeneous coat approximately 0·004 in. thick where resistance to oxidation only is required— or it may be in two coats, the upper being more refractory than the lower, porous, and 0·020 to 0·060 in. thick.

The properties of the coating† depend on the proportion of refractory to matrix, the particle size, the number of layers present, and the porosity of the upper face. It is always non-porous at the metal interface.

Applications

The process has been applied successfully to the emitting surface of black emitter radiant heaters used for space heating and for industrial heating processes.

In a heater of the latter kind in which a black mild steel sheet is heated, a baffle plate is fitted behind it in order to shield the lower part from overheating due to direct exposure to the products of combustion and radiation from the flames. The panel temperature of this appliance was originally limited to 345° C. (650° F.) because, at that temperature, the baffle plate was at about 500° C. (932° F.)

The radiant panels and baffle plates of these appliances are now protected by the Stoneclad process, the finish of the panels being smooth and black or dark grey in colour, its purpose being to prevent rusting and to be and remain of good appearance, while the baffle plates have a comparatively rough, biscuit coloured surface brought about by the inclusion of a higher proportion of refractory material and resulting in a greater resistance to high temperatures and thermal shock.

Test Results

After 1,700 hours heating, tests on an unprotected baffle plate were concluded because the scaled condition of the mild steel was having an adverse effect on the performance of the appliance, and it was felt that the material had therefore failed. Further heating would result in the formation of more scale, which would again lead to incomplete combustion, and eventually the baffle plate would be corroded away completely.

On the other hand, the heater having the panel and baffle plate protected by this process is still operating satisfactorily after more than 7,000 hours. The panel has run at a temperature of about 455° C. (850° F.), and the baffle plate at 620° C., and on occasions the panel has been as high as 475° C. (890° F.), and the baffle 690° C.

Apart from the above application it is used on a number of space-heating appliances and a finish similar to that used for the protection of baffle plates has been applied with success to a fabricated mild steel mixing chamber, used in connection with some experiments in which products of combustion at about 800° C. passed through a central tube while comparatively cool circulated gases were fed into the annulus surrounding the tube before being mixed with the hot gases. Under these conditions unprotected mild steel components had a life of but a few hours, whereas the up-graded mild steel appeared to be in its original condition at the conclusion of the experiments.

The smooth finish as applied to the panels of radiant heaters is claimed to be suitable for use up to a temperature of 670° C. and the more refractory finish applied to the baffle plates for temperatures up to 800° C.

Conclusion

The use of this finish has given encouraging results in the applications mentioned and it is suggested that there may be many instances of high-grade heat-resisting steels being used where temperatures of 500–800° C. are encountered in which mild steel protected by this process would be satisfactory.

* A condensation of report No. 50/4/73 prepared by the Industrial Gas Development Committee of the Gas Council.

† Stones are now formed in thin film on the metal having the additional properties of resistance to acid attack, such as the condensates from combusted fuels, and resistance to abrasion. Their surfaces are harder than chromium and, consequently, give excellent protection against scratching.

Note on the Solubility of Iron in Liquid Magnesium-Aluminium Alloys*

By W. A. Baker, B.Sc., F.I.M. and M. D. Eborall, B.A.

(Communication from The British Non-Ferrous Metals Research Association)

IN the course of a study of the grain refinement of magnesium-aluminium alloys by superheating, a few experiments were carried out to determine the solubility of iron in the molten alloys. It is thought that the present note is worthy of record, although the work was not done with the highest purity basis metals available, and in fact was not designed to establish constitutional data of the highest accuracy.

Experimental Procedure

The solubility of iron in magnesium-aluminium alloys, and in a magnesium-aluminium-manganese alloy, was determined by inserting cylindrical specimens approximately $\frac{3}{4}$ in. diameter and 2 in. long into small cylindrical welded steel crucibles thoroughly cleaned by pickling. Lids were welded on and the crucibles were heated for 24 hours at various temperatures above the melting points of the alloys. The crucibles were then removed from the furnace and quickly quenched in cold water, care being taken not to invert the crucible during quenching.

TABLE I.—SOLUBILITY OF IRON IN MOLTEN MAGNESIUM-ALUMINIUM ALLOYS†

Initial Composition	Treatment	Final Iron Content %	Microexamination
2·3% Al 0·014% Mn 0·036% Fe	24 hrs. 650° C.	0·006	Segregate on bottom of crucible
	" " 750° C.	0·017	" " "
	" " 850° C.	0·051	No segregate
	" " 950° C.	0·065	" "
2·4% Al 0·25% Mn 0·020% Fe	24 hrs. 650° C.	0·003	Segregate on bottom of crucible
	" " 750° C.	0·011	" " "
	" " 850° C.	0·05	No segregate
	" " 950° C.	0·11	" "
	½ hr. 1,150°–1,200°C.	0·49	
5·0% Al 0·10% Mn 0·023% Fe	24 hrs. 650° C.	0·004	Segregate on bottom of crucible
	" " 750° C.	0·015	" " "
	" " 850° C.	0·042	No segregate
	" " 950° C.	0·127	" "
8·3% Al 0·08% Mn 0·027% Fe	24 hrs. 650° C.	0·005	Segregate on bottom of crucible
	" " 750° C.	0·020	" " "
	" " 850° C.	0·051	No segregate
	" " 875° C.	0·065	" "
	" " 900° C.	0·094	" "
	" " 925° C.	0·093	" "
	" " 950° C.	0·120	" "
	" " 950° C.	0·136	No segregate on bottom of crucible; dendritic primaries in body of melt.

†Basis metals :—Magnesium (electrolytic) : 0·03% Fe, <0·01% Si.
Aluminium : 0·15% Fe, 0·15 % Si.
Manganese (electrolytic).

The initial iron contents of the materials are given in Table I, together with the final iron contents found in specimens machined from the cylinders as follows. Approximately 1 in. was cut off from the bottom of the cylinder, a $\frac{1}{2}$ in. discard was made at the top and approximately $\frac{1}{8}$ in. was removed from the sides by turning. The whole of the resulting specimen was dissolved for analysis. It can be seen from Table I that the iron contents found after holding at low temperatures were considerably lower than the initial iron contents,

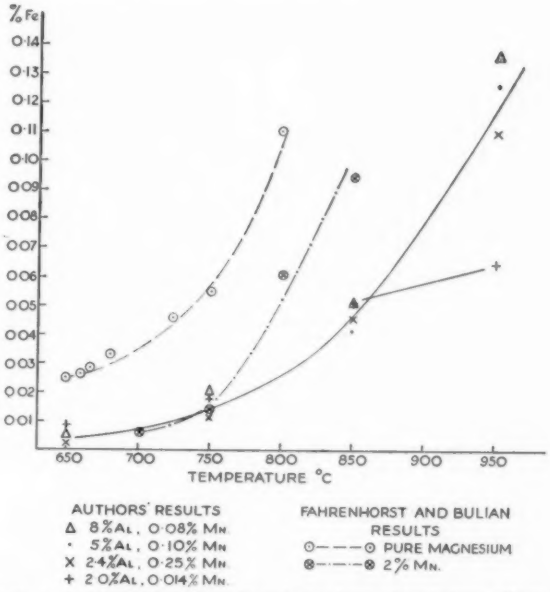


Fig. 1.—Solubility of iron in magnesium-aluminium alloys. Continuous lines indicate authors' results.

and sections of the bottom piece cut from the treated cylinders revealed the excess iron as a gravity segregate. No segregate was found where the iron content of the treated specimen exceeded the initial iron content.

Discussion of Results

The iron contents of the quenched specimens are plotted in Fig. 1, and the curves obtained by German investigators[1] for the solubility of iron in magnesium and in magnesium-manganese alloy are included for comparison. The solubility of iron increases rapidly with temperature in all cases. While the solubility in magnesium-aluminium alloys increases slightly with aluminium content, the solubility curves are all lower than that reported by the German investigators[1] for magnesium. This is in general agreement with Nelson[2] and his collaborators. The presence of 0·25% manganese in the 2% magnesium-aluminium alloy appears to have little effect on the solubility of iron. A few check tests on the effect of soaking time were made by heating specimens to 900° C. for 4 hours only and these had iron contents similar to those indicated by Fig. 1.

Microexamination of specimens showed that when the sample was quenched from a high holding temperature the iron-rich phase formed well-defined dendrites, while if the specimen were allowed to cool in the furnace to a

* *B.N.F.M.R.A. Report* TM88P.

1 Fahrenhorst, E. and Bulian, W., *Z. Metallkunde*, **33** (1), 31–34.
2 Hanawalt, J. D., Nelson, C. E. and Peloubet, J. A., *Trans. Amer. Inst. Min. Met. Eng.*, 1942, **147**, 273–299.

lower temperature, e.g., from 900°–850° C. the iron-rich phase formed well-defined cubes.

Conclusion

It is concluded that the solubility of iron in magnesium-aluminium alloys containing 2–7% Al is little affected by the aluminium content of the alloy, but is markedly dependent on temperature. At 650° C., the solubility is of the order of 0·005%, and the solubility increases rapidly with temperature until at 900° C. it is of the order of 0·07%.

Clean Producer Gas from Bituminous Coal

FOR many years gas producers operating on bituminous coal, especially with the non-caking high volatile variety, have proved to be the most efficient means of using this type of fuel, maximum efficiency being obtained when the gas can be used hot. Control, however, is necessarily rather rough, and the needs of industry more and more demand accurate firing conditions which, in turn, necessitate the use of clean gas. To obtain reasonable efficiency with clean gas the tars must count in as a readily saleable or usable product, but the orthodox water washing process for cleaning bituminous gas produces high water content tars which are, more often than not, a nuisance rather than an asset.

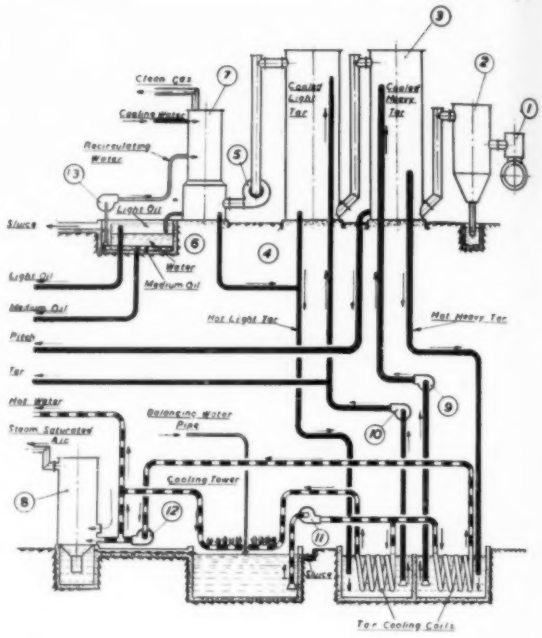
The British licence for a new process has recently been acquired by Messrs. Gibbons Heurtey, Ltd., from Heurtey & Cie, Paris. This process results in a 99·9% degree of cleanliness, giving by-products of good quality pitch and water-free light tar oils. In addition, the sensible heat is recovered from the gas as clean hot water at about 90° C. The overall efficiency is shown in the heat balance below from coal of 13,500 B.T.U./lb.

Gas	9,000 B.T.U.	66·7%
Pitch and Tar Oil	2,250 B.T.U.	16·7%
Clean Hot Water	750 B.T.U.	5·6%
	12,000 B.T.U.	89·0%

The Operation of the Plant.

As a general rule, the hot gas from the producer first passes through a dustcatcher (2); this is not indispensable but it relieves the cleaning vessels of the larger dust particles. The dustcatcher is lined with firebrick and insulation to protect the steel plates and to keep the gas at the correct temperature for its later treatment; the necks before and after the dustcatcher are designed for easy cleaning with the plant at work.

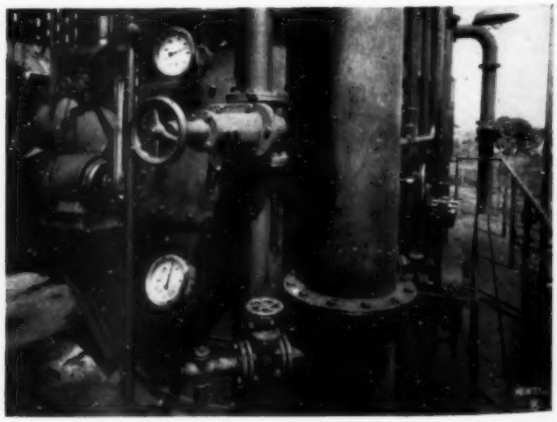
The next vessel (3) is for heavy tar removal, the gas meeting sprays of tar oil which dissolve the heaviest fractions as pitch. This collects in a bath at the bottom



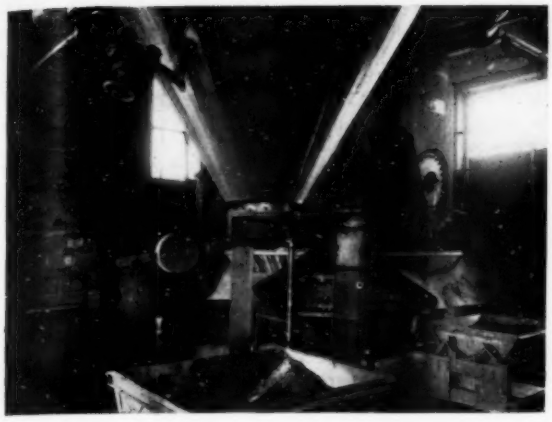
1.—Raw Gas Valve.
2.—Dust Catcher.
3.—Pitch and Heavy Tar Tower No. 1.
4.—Light Tar Tower No. 2.
5.—Booster.
6.—Detarrer.
7.—Washer and Separator.
8.—Air Saturator.
9.—Heavy Tar Pump.
10.—Light Tar Pump.
11.—Cooling Water Pump.
12.—Hot Water Pump.
13.—Circulating Water Pump.

Diagram showing gas-flow through the cleaning plant.

View of the electrically-driven booster fan and of the pipes which convey the raw gas to the pitch column.



The bottom of the pitch column. The pipes from the producer can be seen on the left of the picture.



View of the lower part of the producer and dust catcher.

of the vessel, where, warmed by the incoming gas and agitated by two heavy horizontal stirrers, it overflows to a water bosh.

In the light oil washing vessel (4) the gas, now at a lower temperature after the initial washing, meets a counterflow of light oil over a series of baffles, which absorb the light tar oil fractions in the gas, the products flowing to a storage tank for cooling, recirculation and sale of surplus.

The gas, now free from dust, tar and all but a trace of light oil, is then boosted in a standard centrifugal type booster (5) running on ball or roller bearings and driven direct or through vee ropes, by an electric motor. It should be noted that with this type of cleaning there is no need for a complicated disintegrator, expensive both to buy and run.

Following the booster, the gas travels through a spray separator (6) to remove the remaining light oils and lastly to the final cooler (7). This may either be direct or indirect ; the former is cheaper, but the latter has the advantage that the cooling water is uncontaminated and that the volume of effluent is small.

The gas, now at ambient temperature and containing only vestiges of water and light oil, is ready for piping to the furnaces. Should the plant be situated in a remote part of the works, the gas can, of course, be reboosted.

The hot tar and light oils from vessels (3) and (4) are collected in storage tanks, then pumped (9) and (10) through water coolers back to the cleaning vessels or the storage tank ; the water used for cooling these products recovers some 80% of the sensible heat in the gas, and may be used as feed water or for space heating as desired.

The cleaning plant described will operate with any type of coal suitable for gasification. Should the present uncertain fuel position demand a change-over from bituminous coal to anthracite or coke, this can be carried out by water washing in the primary vessels, but the plant should be shut down and cleaned out before changing from bituminous to non-bituminous fuels, or vice versa.

The products of the new cleaning process are : (*a*) very clean gas ; (*b*) water-free pitch and light oil ; and (*c*) clean hot water. The layout of the plant is compact and convenient, and a high gross efficiency is obtained by the use of the process.

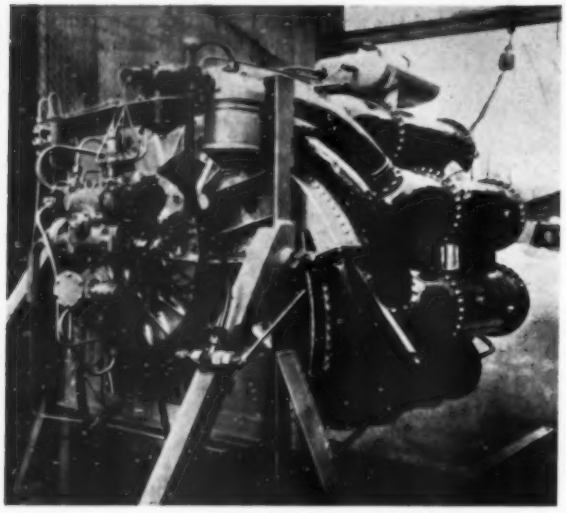
Early Metallurgical Development of the Gas Turbine Engine

Courtesy of the National Gas Turbine Establishment.
The Gloster E28/39

IN the ten years that have passed since the first flight of the Gloster E28/39, the revolution that has taken place in methods of aircraft propulsion is remarkable, bearing in mind that the aircraft industry itself is little over forty years old.

It is interesting to reflect, therefore, on the complex problems which faced the designers, engineers and, in their turn, the steel and alloy makers, in whose hands rests the success or failure of so many enterprises. When work started in earnest on the Whittle jet engine in 1936, the best materials available were only able to withstand the stresses required for the engine up to 500° C. without excessive creep, and the steel used for the initial experimental work was Firth-Vickers "Stayblade." This steel, which itself represented a considerable advance on materials previously available, was a development of the famous "Staybrite" corrosion-resisting steel, and was used for the discs in the W.1 engine which powered the E28/39 on its first flight. In fact, "Stayblade" steel continued in use for discs, because of its higher creep strength, for practically all the development work until the end of 1943.

During the period from 1937–1939 there was a steady improvement in the engine performance, and the conditions imposed on the turbine blades became increasingly severe owing to the higher temperatures attained. However, with the introduction of "Rex 78" steel developed by the Firth-Vicker's research organisation, in 1939, further engine development was made possible. "Rex 78" steel was used for the blades in the W.1 and W.1.X. engines, as it had considerably improved properties at elevated temperatures, being capable of



Courtesy of the National Gas Turbine Establishment

The W 1 Engine

working at a temperature 100° C. higher than other materials under trial at that time. This was a very remarkable achievement, and when the Gloster E28/39 was first flown, powered by the W.1 engine, both the turbine blades and the nozzle blades were made in Rex 78 steel.

This steel made possible the great strides in engine development which took place during 1940 and 1941, in fact, Wing-Commander Frank Whittle (now Air Commodore Sir Frank Whittle) wrote on November 10th, 1941, to the late Dr. W. H. Hatfield: "Indeed without the special steels which you have developed, it would not have been a practicable proposition. You have, therefore, provided an essential link."

The success of the flight proved the possibilities of the jet engine as a prime mover—possibilities which were limited only by the availability of materials capable of withstanding the demands for more arduous conditions, particularly blades and discs with even higher creep strength.

Another development which progressed at the same time as the jet engine was the process of producing rings as components for the engine by the centrifugal casting process. This method pioneered by the Firth-Vicker's foundry, and continuously developed by them, has made the production of these components a sound economic proposition. In the early days rings were made by forming Staybrite F.D.P. and H.R. Crown Max steel bars to ring shape, welding the joint, heat-treating to remove welding and bending stresses, and finally machining the ring to the desired section. This method was used for producing the Staybrite F.D.P. steel rings for the W.1 engine and proved a lengthy and costly business. To-day numerous engine components are made by the centri-spinning process, and with modified techniques complicated sections in the improved heat-resisting steels are in regular production.

Many other components for the jet engine are made from heat-resisting steels in sheet form and operate under conditions of high temperature and stresses. Staybrite F.D.P. Steel was used in the original engine and is still used extensively for this work. Although this steel is a standard corrosion-resisting steel stabilised with titanium, it possesses useful strength and resistance to oxidation at temperatures up to 800° C.

As the jet engine has improved in performance, so the steels and materials used to enable it to function have improved, but the steel manufacturer must always be ahead. These engines could never have reached their present high state of efficiency without materials to withstand their onerous service conditions.

Many different alloys have been developed with varying success, and amongst these Firth-Vickers have more recently developed a series of new creep-resisting steels for turbine discs, rotors and blades for the modern gas turbine—components which have to withstand high stresses at temperatures up to 800° C. or even higher. Firth-Vicker's 326 and 337 steels have been used in various forms from blade stampings to large rotor forgings; Rex 448 is a new ferritic steel which is particularly suitable for aircraft turbine components where service temperatures are not so high as to warrant the use of an austenitic steel; and Rex 467, another recent development, is an austenitic steel which has creep-resisting properties of a very high order, but which does not contain in its composition the more scarce and expensive alloying elements upon which good creep resistance usually depends.

Research continues on both sides, the metallurgical and the process technique. The problems of to-day are attacked on the basis of experience gained in overcoming the problems of yesterday, but they are no less acute than those which were overcome ten years ago, culminating in that historic flight of the Gloster E28/39.

Metals Economy Advisory Committee

THE Minister of Supply (Mr. George R. Strauss), in conjunction with the Lord Privy Seal as Minister of Materials, has appointed an Advisory Committee on Metals Economy, to assist him to ensure the most economical use of metals in the engineering industry and in the Defence Programme.

MR. D. A. OLIVER, Director of Research to the B.S.A. Group of Companies, who recently became Metals Economy Adviser to the Minister, is Chairman of the Committee.

Members of the Committee are drawn from both industry and Government Departments. The Industrial Members are:—

G. L. BAILEY, ESQ., The British Non-Ferrous Metals Research Association.

H. A. R. BINNEY, ESQ., C.B., British Standards Institution.

H. H. BURTON, ESQ., The English Steel Corporation, Ltd.

W. C. F. HESSENBERG, ESQ., The British Iron and Steel Research Association.

E. W. GRINHAM, ESQ., The Standard Motor Co., Ltd.

DR. IVOR JENKINS, The General Electric Co., Ltd.

DR. L. B. PFEIL, O.B.E., The Mond Nickel Co., Ltd.

C. J. SMITHELLS, ESQ., The British Aluminium Co., Ltd.

The Secretary of the Committee is MR. K. M. MCLEOD of the Engineering Industries Division of the Ministry of Supply.

As measures of economy in non-ferrous metals have an effect on and are affected by questions of supply of these metals, the Committee will report to the Minister of Materials as well as to the Minister of Supply.

NEWS AND ANNOUNCEMENTS

Corrosion of Buried Metals

New Pipe Failure Report Form

A NEW standard form for recording corrosion failures of buried pipes has been prepared by the British Iron and Steel Research Association's Sub-Committee on the Corrosion of Buried Metals. It is available from Mr. E. E. White, B.I.S.R.A., 140, Battersea Park Road, London, S.W.11, and is to be returned when completed to the Chemical Research Laboratory of the D.S.I.R., Teddington. The Sub-Committee has taken over from the Research Co-ordination Committee of the Institution of Water Engineers its work on the corrosion of buried pipe lines, and the new form incorporates the changes which the Institution's experience has shown to be desirable.

The seriousness of the problem of underground corrosion, which has been estimated to cost the country £5,000,000 per year, was recognised in the report of the Ministry of Health's Departmental Committee last year, where the importance of full and accurate records of all cases of underground corrosion was emphasised. The B.I.S.R.A. Sub-Committee, under the chairmanship of Mr. L. C. Whiskin of the Metropolitan Water Board and representing the Institution of Water Engineers, is now responsible for the work formerly carried out by the Departmental Committee. It is hoped that the new form will be widely used to report new cases of underground corrosion, especially in pipes laid since 1920.

The Technology of Diamonds and Other Hard Substances

FOLLOWING the successful conclusion of the first nine-lecture course on this subject at the South-East London Technical College, the Mechanical Engineering Department has arranged for a second ten-lecture course on the *Technology of Diamonds and Other Hard Substances*, commencing Monday, October 8th, 1951, with lectures every other Monday until February 18th, 1952. The lectures deal practically with all the technical applications and aim at giving fundamental information on the diamond as a technical material. Special lectures are provided on Shaped Diamond Tools, Diamond Truing Tools, Diamond Dies, Production and Use of Diamond Grinding Wheels, Diamond Rock Drilling, and Production of Sapphire Bearings. The lectures will be given by experts in this field, including J. C. Dawkins, P. Grodzinski, F. C. Jearum, G. R. Leeds, J. D. McClure, B. Morgans and N. Smith. Applications should be sent to the South-East London Technical College, Lewisham Way, London, S.E.4. Telephone: Tideway 1421.

Refractories Lecture Course

A COURSE of ten evening lectures on "Refractories, Their Manufacture, Properties and Uses" will be delivered by L. R. Barrett, M.A., B.Sc., M.S., A.R.I.C., M.Inst.F., at the Northampton Polytechnic, St. John Street, London, E.C.1, on Tuesday evenings at 7 p.m., commencing on October 2nd, 1951. Organised primarily to provide a detailed and up-to-date survey of refractories and the refractories industry for technologists engaged in the metallurgical, fuels, carbonising, glass and chemical industries, the course is also suitable for students of metallurgy and of other related branches of applied chemistry, provided they possess the necessary fundamental knowledge of chemistry. It will also be of value to those preparing for the examinations of the Institution of Metallurgists and of the Institute of Fuel. In conjunction with the course, a limited number of places are available for special laboratory work in refractory technology; those desirous of being considered for these vacancies should apply in writing to the Head of the Department of Applied Chemistry, from whom further details may be obtained.

Heating, Ventilation and Lighting Conference

ORGANISED by the British Cast Iron Research Association, a Conference on Heating, Ventilation and Lighting is to be held at Ashorne Hill, Leamington Spa, from Wednesday afternoon, September 26th to Friday evening, September 28th.

There will be a series of lectures and discussions on various aspects of these topics in relation to the foundry, and the subjects will include: Improvement of Working Conditions in Foundries—Survey of Problems Involved; Incorporation of Dust Control in Foundry Planning; Electric Lamps; Industrial Lighting; Natural Ventilation; Ventilation Methods in Swedish Foundries; Fans: Their Characteristics and Factors Governing Their Selection; Dust in Foundries (including a film dealing with the observation of dust in foundry dressing operations); Methods of Dust Conveying and Dust Collection; Fume and Dust Extraction at the Knock-out; Methods of Foundry Heating; Core Removal and Cleaning of Castings by the Wet Process; Some Experiences in Dust Suppression and Suggestions for Future Work; and Some Experiments in Dust Suppression in the Fettling Shop.

Silica Bricks

DURING the past few years the Coal Carbonisation Plant Committee, which is responsible for the progressing of construction of coke ovens and carbonising plant, has experienced confusion between makers and users of refractories on the meaning of silica bricks, siliceous bricks, semi-siliceous bricks and firebricks.

The Ministry of Supply—which had responsibilities in this field before the Ministry of Materials was formed—was asked to ascertain whether agreement could be obtained between the interested organisations. The Ministry has now reported to the Committee as follows:

Silica Bricks.—Bricks containing at least 92% silica.

Siliceous Bricks.—Bricks containing 85/92% silica.

Semi-Siliceous Bricks.—Bricks containing 78/85% silica.

Firebricks.—Bricks for which the silica content is below 78%.

The British Ceramics Research Association and the Director of the National Federation of Clay Industries were consulted, and are in agreement with the classification. It should also be noted that this classification corresponds with the information in "Technical Data on Fuel."

Steel Rationing

THE Ministry of Supply announces that control over the distribution of the main forms of carbon steel will be introduced on December 3rd, 1951. Roughly 95% of the steel used in Britain is carbon steel.

The Government's decision to introduce this control was made known by the Chancellor of the Exchequer in the House of Commons on June 28th, when he announced the introduction of the present interim arrangements involving the use of "D.O." (Defence Order) and "P.T." (Preferential Treatment) symbols.

The present arrangements for controlling the distribution of sheet steel, tinplate, terneplate and blackplate will remain unaltered.

A further announcement will be made about control over the distribution of alloy steel.

The new arrangements will be similar to those in operation up to May, 1950. As from December 3rd, no person will be allowed to acquire carbon steel in the forms listed, unless he has an "I.S. authorisation." These authorisations will be issued to firms to acquire specific quantities of steel for specific purposes. The authorisation will permit the firm to acquire the steel direct or allow the firm's sub-contractors to purchase steel to fulfil sub-contracts. These arrangements do not apply to building and civil-engineering firms, who will receive a notice from the Ministry of Works telling them how to apply for the steel they need. There will be other variations from the general procedure similar to those that existed before.

Firms which formerly received I.S. authorisations will shortly be asked by the appropriate Department to send in applications for allocations of carbon steel. Ministry of Supply Regional Controllers will ask firms who formerly received I.S. authorisations from Regional Offices to apply to them.

Any steel-using firm, except a sub-contractor, which will be requiring carbon steel and has not had an authorisation before, should apply early in September as follows :—

(1) If the firm requires more than 25 tons of steel a quarter, it should apply to the Department which it normally contacts on matters of production.
(2) If the firm uses 25 tons or less a quarter (including not more than 10 tons of sheet), it should apply to the Ministry of Supply Regional Controller.

In cases of doubt application should be made to the Ministry of Supply, Iron and Steel Division, Shell-Mex House, Strand W.C.2.

I.S. authorisations will not be needed to buy small quantities of carbon steel (1 ton a quarter or less according to the form of steel). Full details of these exemptions for small quantities will be issued later.

Iron and steel stockholders will again need licences to acquire controlled types of steel for resale. Stockholders who previously had licences will be told direct what action to take. Iron and steel stockholders established since May, 1950, should write for a licence to Ministry of Supply, Iron and Steel Division, Shell-Mex House, Strand, W.C.2.

These arrangements apply to ingots and to wrought steel in a wide variety of forms.

WE are advised by High Duty Alloys, Ltd., Slough, that their telephone number has been changed from Slough 21201 to Slough 23901.

Personal News

THE Minister of Transport has appointed MR. E. T. JUDGE, Director and Chief Technical Engineer of Dorman, Long and Co. Ltd., to the Board of the Tees Conservancy Commission.

MR. R. G. H. TAYLOR, Managing Director of Taylor Bros. and Co. Ltd., Manchester, has been elected a Director of the English Steel Corporation Ltd.

SANDERSON BROTHERS AND NEWBOULD LTD., Sheffield, announce the election of MR. W. T. AGAR to the Board.

CATTON AND CO. LTD., steelfounders of Leeds, have appointed MR. S. L. FINCH as a Director. Mr. Finch joined the Company in 1947 as Foundry Manager, and in 1949 was appointed Works Manager.

SIR ARTHUR P. M. FLEMING has relinquished his executive duties as Director of Research and Education for the Metropolitan-Vickers Electrical Co. Ltd., but will retain his seat on the Board. Sir Arthur, who has for some years been Chairman of the A.E.I. Research Committee, which co-ordinates the research activities of the manufacturing companies within the Associated Electrical Industries Group, and the long term research of the A.E.I. Research Laboratories at Aldermaston, will now also undertake the co-ordination of the educational work of the various companies.

METROPOLITAN-VICKERS ELECTRICAL CO. LTD. announce that DR. C. DANNATT, Director and Chief Electrical Engineer, is appointed Director of Research and Education in place of Sir Arthur P. M. Fleming. Dr. Dannatt is also appointed Assistant Managing Director. He is succeeded as Chief Electrical Engineer by MR. H. WEST, who is also appointed to the Board of the Company.

MR. E. RAYBOULD has relinquished his position as Chief Metallurgist of the Foundry Division of High Duty Alloys Ltd., Slough, and has taken up an appointment as Foundry Manager with H. M. Hobson Ltd., Wolverhampton.

MR. J. A. J. BLANCKENSEE and MISS E. P. WOOD (Joint General Managers of the Raw Materials Division of George Cohen, Sons and Co. Ltd.) have been elected to the Boards of Pollock Brown and Co. Ltd., Westbourne Park Coal and Iron Co. Ltd., and Southall and Hayes Coal and Iron Co. Ltd.

MR. P. COOK and MR. F. RIDLEY have been appointed Directors of Daralum Castings Ltd. of Darlington. Mr. Cook has been promoted to General Manager, and Mr. Ridley to Secretary of the Company, and its associate, John Vickers and Sons, master patternmakers of Darlington.

MR. PETER WRIGHTSON, O.B.E., has been elected to a seat on the North Eastern District Board of Martins Bank Limited. Mr. Wrightson is Deputy Managing Director of Head, Wrightson and Co. Ltd.,

Obituary

WE regret to announce the following deaths :—

SIR ROBERT STEWART JOHNSON, chairman of Cammell Laird and Co. Ltd., who died at his Birkenhead home on August 28th, at the age of 79.

MR. J. KILBRIDE, progress and planning manager for Samuel Fox and Co. Ltd., Stocksbridge, who died in Sheffield Royal Infirmary on August 11th.

RECENT DEVELOPMENTS
MATERIALS : PROCESSES : EQUIPMENT

Electronic Press Guard

A NEW type of automatic guard for power presses and similar machines has been developed by the Witton-Kramer Works of The General Electric Co., Ltd., and a prototype equipment fitted to a Taylor and Challen press was recently demonstrated at a Safety Exhibition organised by the Birmingham and District Industrial Safety Group. This press complete with its electronic guard is shown in Fig. 1.

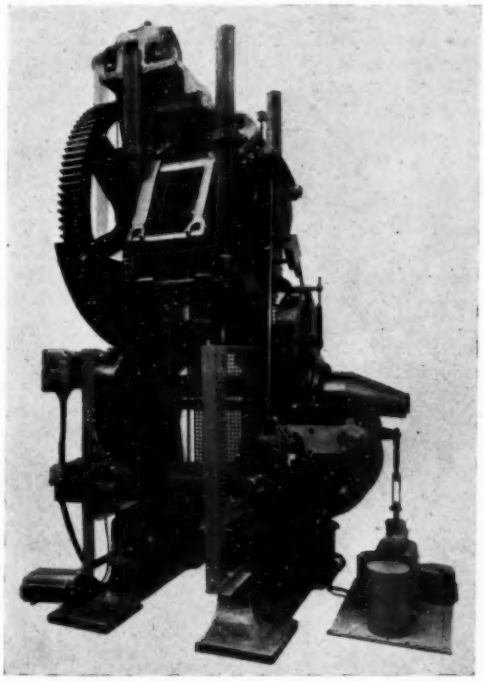


Fig. 1.—The G.E.C. electronic press guard fitted to a Taylor and Challen press.

An important feature of the new guard, which occupies less space than the usual mechanical guard, is that the operation of the electronic equipment is automatically checked at each complete stroke of the press, so that immediate warning is given should any fault develop in the system, thus preventing the operator from continuing to work under a false sense of security.

The equipment is mounted on vertical columns fixed at each side of the front of the press. A lamp house at the top of one column projects a beam of light across the front of the press on to a mirror on the opposite column, and this beam is then reflected backwards and forwards by a series of mirrors until the whole area between the columns is traversed by the beam, forming a barrage of light rays.

The light beam is reflected by the last mirror into a receiver unit comprising a photo-electric cell and an amplifier, and a relay in the output stage of the amplifier interlocks the operation of the press to ensure that it cannot be worked whilst any part of the operator is interrupting the light beam and is in consequence in the danger zone. The press is, therefore, free to operate only when the light rays are not obstructed, and in the event of the operator placing his hand in the danger zone whilst the tool is descending, the press is automatically stopped by means of a solenoid which declutches the driving shaft and immediately applies a brake. After tripping in this way, it is not possible for the slide to be set in motion again by power until the safety device has been completely restored to its normal condition.

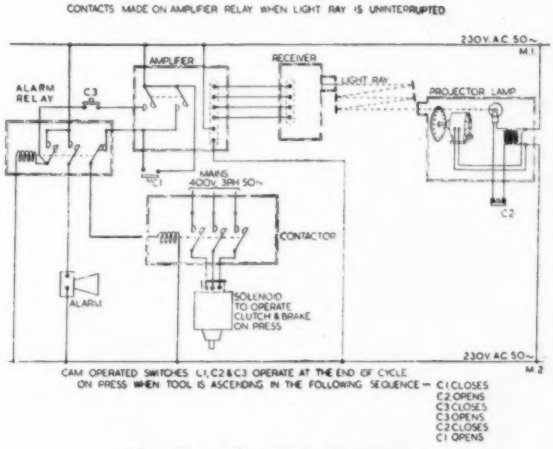


Fig. 2.—Schematic diagram.

A schematic diagram of the guard is shown in Fig. 2. A low voltage lamp energised from a transformer is employed as the light source, and to ensure reliability the lamp is under-run so that the light output is mainly red. To avoid the photo-electric equipment being affected by stray light and changes in external lighting conditions, the beam is modulated by means of a rotating disc mounted in the lamp house.

After leaving the lamp house the light beam is reflected backwards and forwards across the front of the press by means of 17 mirrors mounted in two groups on the vertical columns, and is finally directed into the receiver unit which contains the photo-electric cell which is connected to its associated amplifier. The output stage of the amplifier includes a relay with contacts which only close when the light beam is uninterrupted, and these contacts are used to operate a contactor which energises a solenoid operating the clutch and brake mechanism of the press. This solenoid is connected to the operating mechanism of the press in such a manner that the slide can only be set in motion when the solenoid is energised.

The automatic check on the equipment is initiated by a cam mounted on the main shaft of the press, which is arranged to interrupt the beam momentarily towards the end of each cycle of operations and thus cause the relay in the amplifier to operate. This cam also operates a pair of contacts associated with the alarm relay, and provided the photo-electric relay has operated before the cam-operated contacts are made, the alarm relay does not operate, and when the light beam is restored, the

press is ready for the next operation. If, however, some fault is present in the photo-cell or the amplifier, and the photo-electric relay fails to operate for any reason whatever when the light beam is interrupted, the cam-actuated contacts trip the alarm relay. Audible and visible warning of the fault is given by means of a klaxon horn and indicating lamp, and the press is stopped.

The General Electric Co., Ltd., Magnet House, Kingsway, London, W.C.2.

Die-Casting Machine

THE IMP/96 die-casting machine has been developed from their popular M55A/HF machine by Die Casting Machine Tools, Ltd. It is designed to to do work above the capacity of the M55A/HF, and incorporates a new pilot-operated impact injection unit, together with a power-operated d e-locking and opening unit manipulated by finger-tip controls.

The impact injection unit consists of a specially designed cylinder with a pilot-operated slide valve integrally built into the cylinder head. This unit is interlocked by means of a small valve at the side of the machine which prevents it from being operated until the dies are closed and locked. The main reason for employing such a unit was to permit the use of the same metal pressures as hitherto (80 to 100 lb./sq. in.), on larger diameter metal plungers, which increases the capacity of the shot to 12 oz. in zinc.

The power-operated die unit, which carries die blocks $6 \times 9 \times 1\frac{1}{2}$ in. for effective projected area of castings up to 12 sq. in., has an opening of 4 in. and a formidable lock through four toggles of 12 tons, working through two hardened and ground heavy-duty tie bars of special steel. The unit is powered by an air cylinder of ample capacity to eject castings that offer stubborn resistance to ejection and at the same time smooth in movement and economic in air consumption. The complete cycle takes only 0·55 cu. ft. free air at 80–100 lb./sq. in.

Die Casting Machine Tools, Ltd., River Works, 152, Green Lane, London, N.13.

Magnesium Alloy Dust Collection

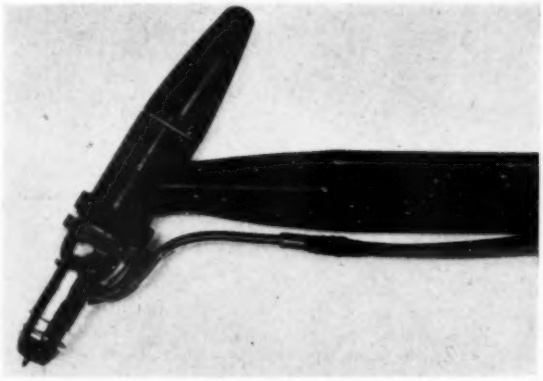
THE Multswirl patent unit dust collector is designed to solve the problem of collecting dust from grinding and polishing operations on magnesium alloys, thus complying with the precautions laid down by the Factories Act. The dangerous dust is collected and thoroughly immersed and scrubbed in a water chamber (the design of a special duct incorporated within the collector allows the dust-laden air to pass through three water submersions). Should the velocity of air-flow in the extraction ducts fall for any reason below the requisite speed for efficient collection, an automatic device stops the grinding or polishing machine. The machine cannot be restarted until the air-flow is restored. This similarly applies to the water level should it fall, due to evaporation or any other reason, below the level set for efficient scrubbing of the dust. In further compliance with safety requirements a time switch is incorporated to ensure that the unit fan runs for a period of five minutes so that any latent gases which may have accumulated, perhaps overnight, are cleared before the grinding or polishing machine is started up. Explosion releases are also fitted to the equipment. The electrical control devices fitted within the Multiswirl collector make sure that the operator cannot work his machine without the dust collector working in an absolutely efficient manner.

This type of unit is now being made in a range of models; the first a bench type model, the top of which consists of plastic-covered rollers spaced $\frac{3}{8}$ in. apart and on which the component to be fettled or ground is placed, so that the heavy dust particles fall immediately into the water chamber underneath; the light floating dust is collected by means of a telescopic universal fitting under suction. The second model is for double-end polishing spindles, the spindles being mounted on the unit itself; this unit is similar in principle to the one described above. It is provided with the well-known Dallow Lambert Mark II polishing hoods, in place of the plastic rollers and the telescopic universal fitting. The third model is the booth type and is similar to the bench model, but in this case the upper half is provided with a booth which contains the telescopic universal fitting. A suitable air velocity is maintained within the booth, and the universal fitting can be moved by the operator to any desired position.

Dallow Lambert & Co., Ltd., Spalding Street, Leicester.

Argonarc Torch Shield

DEMAND for a torch capable of dealing with currents up to 350 amps. has produced a useful accessory in the form of a water-cooled shield for use on the Argonarc Mark III Torch. This accessory was introduced at the Engineering, Marine and Welding Exhibition and is described fully in a leaflet which is now available. The leaflet includes information reference fitment to the standard Mark III equipment. As stated, the new accessory permits constant use of current up to 350 amps. in welding thicknesses of up to $\frac{1}{4}$ in. copper and $\frac{1}{2}$ in. aluminium plate without any danger of overheating or shield failure.



Argonarc Torch Mk. 3 with water-cooled head.

The components are: (1) Chromium-plated copper water-cooled shield; (2) insulated shield adaptor; (3) interchangeable nozzles in three sizes; (4) a T-junction for hose connections; (5) 15-ft. of P.V.C. tubing for the water drain; (6) 9 ft. of P.V.C. tubing for connection to the master valve; (7) steel hose clip; and (8) lengthened collet key for electrode removal.

It is felt that with its undoubted advantage over the ceramic shield where the continued use of heavy currents is involved, the water-cooled shield will prove to be a popular piece of equipment.

The British Oxygen Co., Ltd., Bridgewater House, Cleveland Row, St. James's, London, S.W.1.

CURRENT LITERATURE

Book Reviews

A BIBLIOGRAPHICAL SURVEY OF THE DEVELOPMENT AND USE OF SUBSTITUTE MATERIALS FOR NON-FERROUS METALS AND ALLOY STEELS IN GERMANY

Report No. B.M.S.–2. Published for the Technical Information and Documents Unit, D.S.I.R. by His Majesty's Stationery Office, London. 1s. 6d. (40 cents U.S.A.), by post 1s. 7½d.

BEFORE and during the war the Germans were forced to find substitutes for such metals as tungsten, copper, tin, nickel and lead for a wide variety of purposes, and they displayed considerable ingenuity in doing so. This survey, containing as it does information on the work they did, will be of great value to British industry at a time when the demand for many metals, both imported and home produced, has outstripped supply, and when shortages are likely to prove a problem for many industries in this country.

The Survey consists of short summaries of the more useful papers and is made up from intelligence reports and captured German documents. The sections covered include: (1) Substitute materials for bronze and white metal bearings; (2) Substitute materials for electric cable covers and sheaths; (3) Alloy steels developed to avoid the use of metals in short supply; (4) Surface coatings for steel, especially those which can replace tinning or galvanising; (5) General substitution and new manufacturing processes developed to conserve scarce materials; (6) Food cans and containers developed to avoid the use of tin; (7) Substitutes for tungsten in sintered carbides for tipped tools and dies; (8) Steel cartridge cases (to replace brass). The Survey gives details of the means whereby copies and/or translations of the various documents can be obtained.

STATISTICAL YEAR BOOK FOR 1950. PART I. UNITED KINGDOM STATISTICS

Published by the British Iron and Steel Federation, Steel House, Tothill Street, London, S.W.1. Price 7s. 6d.

THIS volume gives the fullest information concerning the U.K. iron and steel industry in all its aspects. Besides iron and steel production, finished steel deliveries and the use of raw materials, the tables give details regarding imports, and exports, prices, stocks and employment in the industry. They are conveniently grouped according to subject, beginning with iron ore and working through the various sections of the industry to the overseas trade statistics.

For the convenience of the general user, two summary tables included at the beginning give information for a long run of years. The first brings together the main statistical series relating to iron ore, coke, pig iron, scrap and steel. The second sums up the information regarding the supply and disposal of steel. It shows, for example, that the total supply (including imports) rose from an annual average of 8,370,000 tons in 1921–25 to 11,220,000 tons in 1938 and to 17,430,000 tons last year. Over the same period, home deliveries advanced from 5,050,000 tons to 14,180,000 tons.

STATISTICAL YEAR BOOK FOR 1949. PART II. OVERSEAS COUNTRIES

Published by the British Iron and Steel Federation, Steel House, Tothill Street, London, S.W.1. Price 15s.

DETAILED statistics for all the steel-producing and the most important steel consuming countries of the world are presented in this publication. They include figures for the production of fuel, iron ore, pig-iron and ferro-alloys, crude steel, and finished steel, together with an analysis of the imports of raw materials and finished products according to country of consignment, and details of the exports of the same items and their destinations. In addition, three tables are included showing, respectively, the world production of iron ore, pig iron and steel, by country, for a long period of years.

REPORT OF THE SECOND CONFERENCE OF INDUSTRIAL RESEARCH DIRECTORS AND MANAGERS.

Federation of British Industries, 21, Tothill Street, London, S.W.1. Price 3s.

THE Report of a week-end conference organised by the F.B.I. Industrial Research Committee at Ashorne Hill, Leamington Spa, in November, and attended by industrial research directors and managers, is now published in book form. Sir Wallace Akers presided at the conference which took for its theme: The Planning and Financial Control of Industrial Research.

Subjects and speakers at the three main sessions were: The planning and budgeting of research—Mr. C. Paine (Imperial Chemical Industries) and Mr. T. C. Williams (Slumberland-Research-Limited); the cost of research—Dr. J. W. Jenkin (Tube Investments, Ltd.) and Mr. C. F. Kearton (Courtaulds, Ltd.); the evaluation of research—Dr. W. Wilson (General Electric Co., Ltd.) and Mr. R. K. Sanders (The Metal Box Co., Ltd.).

The discussion at the session on planning and budgeting raised many questions: who, apart from the research director, should plan the research programme? To what extent should production and commercial departments be consulted? How do research ideas arise—solely in the research department, or also in other departments? What is the value of market research as an aid to planning industrial research? The answers to such questions varied with the type of firm and the scale on which it undertook research. Roughly speaking, the larger the research department the greater the measure of autonomy enjoyed by the research director. One important point that emerged on the budgeting of research was the difficulty of presenting the research programme in non-technical terms so as to convince the company's board of directors that the proposed expenditure was justified.

On the costing of research there were two points of view. Detailed costing, comparable with that practised in production departments, calls for cost accountants, progressing, job numbers, time sheets, and so on. To some research directors these techniques are a denial of the research spirit and a discouragement to the research worker who cannot be expected to produce original ideas at predetermined intervals. However, it is clear that research directors who believe in fairly detailed costing

recognise that it must not be carried beyond reasonable bounds; even with inaccuracies as high as 10% they still regard costing as worthwhile.

Divergent views were held on the evaluation of research. All research directors agreed that it was essential, but few of them had devised any objective method of evaluation. The nearest approach to such a a method was based on the numbers and value of patents arising from the work of the research department. However, even this was not regarded as a very satisfactory yard-stick. Most research directors prefer qualitative to quantitative evaluation. Discussion at the Conference, therefore, centred mainly on the qualitative factors to be assessed; for example, the contribution of the research department to the firm's competitive power, general prosperity and prestige.

Trade Publications

A REVISED and enlarged catalogue dealing with Heliocentric Speed Reducers has recently been issued by Sanderson Brothers & Newbould, Ltd., Newhall Road, Sheffield. A high torque is transmitted by these reducers, which can be supplied for use with 0·25–30 h.p. motors, and which are available in ratios ranging from 20 : 1 to 512,000 : 1 in single stage, duplex, and triplex units. Not only can they be applied in horizontal, ceiling or vertical positions, but they are also particularly suitable for conveyor installations, since the reducer can be fitted inside the drum or pulley. Details are given of the sizes of the various models, together with torque tables and examples of special adaptations.

No. 2 of the Metro-Cutanit Bulletin contains notes on the various grades of Atomit Hard Metal, together with details of the standard cutting tips available. British, DIN and Swiss standards are covered and the working conditions for the various grades of Atomit are given in British and metric units. Reference is also made to Neo-Atomit tips, having a special metallic surface which eliminates the troubles encountered in brazing the tips on to the shank, as a result of the difficulty of wetting the surface with the brazing metal. Copies may be obtained from Metro-Cutanit, Ltd., 160, Piccadilly, London, W.1.

THE remarkable heat-resisting properties of nickel and of its alloys with chromium and iron are well known. On heating in air, these alloys develop adherent oxide films with refractory properties which prevent the progressive oxidation and scaling experienced with steel and many non-ferrous materials. These alloys not only resist progressive oxidation, but also possess good mechanical properties at high temperatures, so that failure of heat-treating equipment due to sagging, distortion, etc. is minimised, and the necessity for large heavy structures which wastefully absorb heat is reduced. Furthermore, the range of materials now available will meet a wide variety of operating conditions. A new publication, "High Nickel Alloys for Heat-resisting Equipment," issued by Henry Wiggin & Co., Ltd., discusses the high temperature properties of Nimonic 75, Inconel, Nimonic D, Mangonic and pure wrought nickel, and by quoting actual uses it gives guidance to the most economical choice of material for a given set of conditions of temperature, loading and requisite life. Copies may be obtained free of charge on application to Henry Wiggin & Co., Ltd., Wiggin Street, Birmingham, 16.

A NEW G.E.C. publication deals with the magnetic sorting bridge which was developed during the war by the Salford Electrical Instrument Works of the G.E.C. in conjunction with the Aero Engine Division of the Ford Motor Company with a view to obtaining a non-destructive method of testing ferrous samples for variation in chemical composition, heat treatment, hardness, depth of carburisation and the like. After a consideration of theoretical principles and circuit details, the interpretation of the patterns obtained on the cathode ray oscillograph is discussed.

With the advance of steam turbine design, the importance of clean, efficient lubrication has become greater, but at the same time the conditions imposed on turbine oil in service have greatly increased in severity. Provision of lubricants able to meet the more exacting modern requirements has given rise to difficult technical problems whose solution has called for enterprise and resource. A booklet available in the U.K. from Shell-Mex & B.P., Ltd., Shell-Mex House, Strand, London, W.C.2, bearing the title "The Lubrication of Steam Turbines" presents an outline of present-day technique in this field.

FOLLOWING the successful introduction earlier this year of their Radian (New Type) electrode for mild steel welding, The Quasi-Arc Co., Ltd., Bilston, Staffordshire, have now issued a six-page technical circular giving details of the mechanical properties and chemical composition, welding technique, deposition and packing data, as well as the applications and characteristics of the electrode. Copies of this new technical circular can be obtained from The Quasi-Arc Co., Ltd. at the above address.

THE Alar Data Sheet, "Guide to the Selection of Aluminium Casting Alloys" has now been revised in terms of the British Standard 1490 "LM" Specifications. Although this series is now widely known, cross references to older designations are given for the benefit of those not familiar with the new LM numbers. The opportunity has been taken of revising the data sheet in a number of other respects.

Books Received

"X-RAY Analysis of Crystals." By J. M. Bijvoet, N. H. Kolkmeyer and Caroline H. Macgillavry. 304 pp. inc. index. London, 1951. Butterworth's Scientific Publications. 50s., by post 1s. extra.

"The Hardness of Metals." By D. Tabor. Tenth volume in the series of Monographs on the Physics and Chemistry of Materials. 175 pp. inc. indices. Oxford University Press, 1951. 15s. net.

"Principles and Methods of Sheet-Metal Fabricating." By George Sachs. 526 pp. inc. index. Reinhold Publishing Corporation, New York, and Chapman & Hall, London. $10 or 80s. net.

"Hot Dip Galvanizing." Report of a visit to the U.S.A. in 1950 of a specialist team representing the hot dip galvanizing industry. 57 pp. Anglo-American Council on Productivity, 21, Tothill Street, London, S.W.1. 3s. 6d. post free.

"Welding." Report of a specialist team which visited the U.S.A. in 1950. 74 pp. Anglo-American Council on Productivity, 21, Tothill Street, London, S.W.1. 3s. 6d. post free.

METALLURGICAL DIGEST

Tallow Can Replace Palm Oil in Hot Dip Tinning

By G. C. Terence and W. R. Johnson

THE undesirability of the American hot dip tinning plants being dependent on palm oil imported from the East Indies and North Africa, together with the steep rise in price, provided an incentive for a search for possible strategic and economic substitutes. As a first step, an appraisal of the properties of palm oil responsible for its effectiveness was undertaken.

In making hot dip tinplate, sheets of pickled steel are passed by means of rolls through a flux into a bath of molten tin and up through an 18-in. layer of hot palm oil floating on the tin. Three sets of rolls, operating in the oil, smooth and thin the tin coating while the hot oil keeps the tin from freezing.

It was soon established that a tinning oil must possess a fluxing action; i.e., it should possess the ability to remove tin oxide from a molten tin surface. A simple test for assessing the efficiency of an oil in this regard comprises adding some 7 g. of oil to the surface of molten tin kept at a temperature of 465° F. in a petri dish. An active oil parts and exposes the tin surface by rapid dispersion of the oxide film, and the length of time over which the oil directs the tin is a rough index of its useful life. An inactive oil lies quiescent on the surface of the tin. It was determined that the free fatty acid content of the palm oil was responsible for its fluxing action by acting as a dispersing agent for tin oxide. Analysis shows that there is no chemical reaction between palm ilo and tin oxides, although there is with tin.

A satisfactory oil must drain rapidly from the tinplate emerging from the pot, otherwise the oil consumption becomes prohibitive and difficulties arise with the cleaning processes. It was found that the oil break in the tin pot and the speed with which the oil drains from the emerging sheet are related to the oxide removal properties of the tinning oil and thus to its free fatty acid content. The layer of oil drains from the sheet until the oil film is sufficiently attenuated for oxygen to diffuse through to the molten tin. Once the oil break starts, it proceeds rapidly because the oxide film which forms instantaneously at the exposed molten tin surface, slides rapidly down the sheet by the pull of the oil. The oil drainage thus proceeds by a tin oxide-tin shear, rather than by the shear of one oil layer over another, as is the case for drainage of an inactive oil, such as mineral oil.

Oil viscosity at pot operating temperatures is important, because if the viscosity is too high, the initial attenuation of the oil on the emerging sheet cannot occur fast enough to give a complete break. At wet washer temperatures, oil viscosity has a direct bearing on the ease of cleaning and branning. Palm oil in a tin pot increases in viscosity due to polymerization and the formation of metallic soaps. Fresh oil must be added at intervals because of oil losses due to volatilisation and drag-out on the tin plate. Only if the replenishment rate is great enough, is the increase in viscosity negatived.

The oil used must also be non-toxic and preferably edible, must not interfere with can-making procedure, and must, of course, be economical.

As a result of the fundamental studies, enough information was obtained to suggest that a specialised modification of beef tallow might prove an ideal substitute for palm oil. Chemically the two are similar in that they are fatty acid esters of glycerine. Beef tallow contains a substantially lower amount of linoleic acid which is considered the major cause of the viscosity increase in palm oil. Any desired amount of free fatty acid can be added to tallow to obtain the activity of palm oil, and although this lowers the flash-point, there is a good margin of safety.

The results of laboratory tests on beef tallow were encouraging enough to warrant a production hot-tinning test at the plant of Weirton Steel Co. The special tinning tallow was purchased and made to specification. The product was made from a beef tallow base, deodorized by commercial processes until only a bland odour remained. Free fatty acids, consisting of acids split from hydrogenated tallow, were added to conform to the desired level determined experimentally (analysis showed 9·6%).

The tallow was charged directly to the tin pot without preheating, contrary to the normal practice with palm oil. Since the tallow was water-free, all additions of fresh tallow were made without fear of foaming or splattering. Prime plate was produced immediately; the tin pot ran smoothly, producing the normal output with somewhat less menders than the average with palm oil. The oil break from the emerging sheet was satisfactory throughout the run, thus, at no time was it necessary to bale out during the run in order to reduce the viscosity.

A total of 17,000 base boxes of 1·25 lb. tin plate was produced with menders averaging under 1%.

The tin yield was quite normal and the average oil consumption was 0·22 lb. of oil per base box produced. This consumption compares favourably with the industry average of 0·3 lb. in the case of palm oil. Wet washer operations proceeded normally, and bran consumption after the wet washer was only 0·5 lb. per base box. The oil coating weight on the cleaned and branned steel was normal, and the finished plate was at all times bright and clean.

Scotch tape lacquer adhesion tests applied to phenolic lacquers were run on the finished tinplate with no failures recorded. Baking discoloration tests, consisting of heating the plate at 410° F. for half an hour, likewise showed no failures.

Analysis of the free fatty acid content of the tallow in the tin pot showed 9·6% at the start, a low of 7·0% during the run, and a high of 11·5% at the conclusion of the test. The ash content of the oil at the end of the run was 2·3%, which was in line with the ash content of used palm oil.

The experimental laboratory tests and the production run substantiated modified beef tallow as a potential hot dip tinning oil; time and continued experience with it in the mills, however, will be the only true test of its worth.

A much larger quantity of palm oil is used in the cold reduction of steel and work is at present being carried out on this phase of the problem at the

From *The Iron Age*, August 2nd, 1951, **168**. 86-89.

Armour Research Foundation. If, as is hoped, some tallow derivative proves to perform on the mill as well as, or better than, palm oil, wide scale substitution would free the mills from dependence on imported palm oil.

Coolant Flood Improves Carbide Performance

By Wackch Iwascheff

ALTHOUGH considerable improvement in the performance of high-speed steel cutting tools has resulted from the correct application of coolants, the use of the latter with carbide tools has been considered both inconvenient and unnecessary. Recent tests have shown, however, that a copious flow of emulsion to carbide tools can effect great improvements.

Results of a large series of shop tests are much more convincing to production men than laboratory tests, since the attitude of the machine operator is taken into consideration. The author conducted shop tests with five Fay automatic lathes having 37½-h.p. drives. A steel-cutting grade of carbide brazed on to steel tool shanks was used to machine 40,000 shell forgings of 0·60 C steel, 6 in. dia. and 20 in. long, with each machine finishing 8,000 pieces. With little effort the objection to coolant spray was eliminated.

TEST CONDITIONS

True rake angle, deg.	4
Relief angle, deg.	5
Side cutting edge angle, deg.	15
Ridge (primary rake) width, in.	0·008
Cutting speed, f.p.m.	300
Feed per rev., in.	0·030
Depth of cut, max. in.	¼
Coolant, oil-water emulsion ratio	1 : 100
Coolant temperature range, ° F.	77–81
Tensile strength of forgings, lb./sq. in.,	100,000–114,000

TOOL LIFE COMPARISON

Coolant jet through ⅜ in. dia. pipes	450 workpieces
Coolant jet through ⅛ in. dia. pipes	325 ,,
Coolant spray	430 ,,
Dry turning	190 ,,

Various cooling arrangements were tried. Small holes, 3/64–⅛ in. dia. were spaced at intervals of 1/32–¼ in. along ½-in. dia. pipe for one trial. Coolant was supplied at the centre of the pipe which was rigidly fastened to the lathe. For each of the four tools, 1·3 g.p.m. was provided. In another series of tests, each tool was supplied with coolant at the rate of 4 g.p.m. through separate ⅜-in. dia. pipes.

Tools were kept in operation until regrinding became necessary. Average tool life per tip under the various cooling arrangements is given in the accompanying table.

Although the pressure was not measured it was adjusted in a manner such that the coolant not only flooded the tool point and workpiece, but, formed an enveloping sheet of liquid over the workpiece. Cooling action improved with an increase in the thickness and uniformity of this liquid sheet. Maintenance of an adequate liquid sheet must be established by checking the coolant supply. A valve was adjusted until the coolant clung to the workpiece; tight clinging indicating that the pressure and quantity of coolant were correct.

Proper adjustment depends on the speed in r.p.m. and the workpiece diameter. The coolant will begin to spray when the speed is too high. Because centrifugal force is great in comparison with the adhesive force, it is impossible to maintain a film of coolant on the side of the workpiece opposite the tool.

In dry turning the cutting edge changed rapidly through cratering or chipping or both; craters reached a depth of 0·040 in. Because of the necessity for keeping the tool at the same level, and to eliminate extensive regrinding, tools were changed before cratering had proceeded to too great an extent. None of the tools had a chip-breaker.

The tool wear was only 0·020 in. after 782 pieces machined with coolant in comparison to the much greater wear after 65 and 155 pieces were turned without coolant. When turning with coolant, no real cratering took place, though a hot spot appeared on the tool. Small cracks which later became fractures developed in the carbide tip when turning without coolant but were not observed when turning with coolant.

Comparative wear resistance can be ascertained from the number of tool adjustments necessitated by tool wear during each working shift. Tools had to be adjusted 10–20 times per shift when turning dry and only 2–4 times per shift when turning with coolant.

In turning the 40,000 forgings with proper use of coolant, cutting speed was increased from 215–300 s.f.p.m., while tool life was extended as much as ten times. This naturally reduced the time required for tool adjustments and regrinding, and meant that carbide was more economically used. The built-up ridge at the cutting edge of the tool was eliminated or at least decreased.

From *The Iron Age*, July 19th, 1951, pp. 86–89.

The Effect of Grain Direction on Mechanical Properties of Light Alloy Extrusions

By D. M. McElhinney

IT has been generally accepted for some time that the mechanical properties of light alloys varied with the direction of the grain, but even in the design of aircraft structures only a slight allowance has been made for this variation. The importance of this grain direction on the strength of light alloys was first realised as a result of the abnormally low test strength of one lug made from a 6½-in. dia. DTD 683 extruded bar.

This initiated a series of tests carried out by Vickers-Armstrong at Weybridge on specimens made from light alloy extruded bars of large cross-sectional area to determine the effect of grain direction on the mechanical properties.

The results of the tests are given in tabular and graphical form. It is concluded that the loss of strength due to transverse grain is much greater than the 10% allowance assumed in the past, being in some cases as great as 35%. With stress concentrations greater than 2 the reduction in tensile strength is as much as 45%. The loss of strength appears to be associated with the small ultimate elongation, sometimes practically nil, obtained in the transverse direction. Pin-shear was not significantly affected by grain direction. The calculation of the strength of lugs is much more complex than has hitherto been assumed, but a reduction of the order of 10% in the normal strength adequately covers the effect of transverse grain. The variation across the bar of the strength of specimens cut from the same bar and in the same direction is much greater than has been expected.

From *Aircraft Eng.*, **23**, 62-66, March 1951. (Abstracted in *Light Metals Bulletin*, **13**, 9, 307.)

LABORATORY METHODS
MECHANICAL · CHEMICAL · PHYSICAL · METALLOGRAPHIC
INSTRUMENTS AND MATERIALS
SEPTEMBER, 1951 Vol. XLIV, No. 263

Notes on the Production at N.P.L. of Alumina and Other Ware for Research Involving High Temperatures*

By Vaughan H. Stott, D. Sc.

The techniques used in making sintered alumina, both for laboratory ware and other purposes, often cause difficulty to those with no previous experience in the field. On the other hand, various research laboratories have been in the habit of manufacturing their own alumina bodies for some years past. These laboratories recently prepared papers on their techniques for the Sintered Oxides Sub-Committee (Inter-Service Metallurgical Research Council, Admiralty and Ministry of Supply), and the information gathered is now released in the hope that it may be useful to those desiring guidance. Most emphasis is placed on the slipcasting method in this series of papers published by kind permission of the Chief of the Royal Naval Scientific Service, and the Chief Scientist, Ministry of Supply. This is the fourth paper of the series.

THE following is an account of the methods used at the National Physical Laboratory in the production of alumina and other refractory ware for use in high-temperature research work. It was written mainly for those already engaged in such research, who would, consequently, be likely to have some acquaintance with the main methods of production. The methods are described in some detail, but considerable practice may be necessary to attain success with certain of them.

PRODUCTION OF DENSE ALUMINA WARE

General

Dense alumina ware is chiefly produced by casting a fine alumina slip in a plaster mould, and firing the product to a high temperature. The process differs considerably from that which is used for clayware. In the latter case the shrinkage in the mould is considerable, and must be kept as small as possible by the addition of a dispersant to the slip. This addition reduces the water content of a slip for a given viscosity, and the reduced water content results in a reduced drying shrinkage. On the other hand, slip-cast alumina has a very small drying shrinkage, and tends to stick to the mould. A well dispersed, slightly acid slip (having a *p*H value of about 4) yields a casting of relatively high bulk density. On hard firing such a casting, the shrinkage is relatively low; for the initial bulk density is high, and the final bulk density cannot exceed that of corundum. Unfortunately, the drying shrinkage is extremely small, so that the removal of the casting from the mould is difficult. It is, therefore, common practice to increase the amount of hydrochloric acid in the slip to about 5% concentrated acid by volume (about *p*H 0·2). The acidity of the slip seriously reduces the life of the moulds, for which reason we prefer to use a slip having an acidity lower than that corresponding with maximum dispersion.

Preparation of Slip

Our slips are usually made by milling dry commercial calcined alumina with steel balls until half the material has a grain size below 3 to 4 μ. Alumina slips age slowly in such a way as to become difficult to cast, and the ground material is, therefore, stored dry until needed. The powder is then freed from iron by cold treatment with dilute hydrochloric acid (1 volume of strong acid to about 15 volumes of tap water). The mixture, in a large glazed earthenware vessel, is stirred with a wooden pole, and allowed to settle, the supernatant liquid being then siphoned away. The alumina is washed several times with weaker and weaker acid, and then with tap water. Settling is fairly quick in the early stages of washing with water, but it may happen that a *p*H value of about 4 is reached in the process, and settling becomes very slow. In such a case, the settled material forms a hard cake which cannot easily be mixed with water. A few drops of ammonia added to the suspension cause rapid settling, but afterwards the slip is unsatisfactory, however thorough further washing with water may be. If, therefore, we find that a particular suspension is very slow in settling, we add just enough hydrochloric acid to produce flocculation. At the next addition of water the *p*H value is generally such that the alumina is again well dispersed. After a sufficient time has been allowed for settling, and after the clear liquid has been siphoned away, the remaining slip is too thick for normal casting. It is, therefore, diluted with tap water to an extent depending on the nature of the article to be cast. An experienced worker can judge the suitability of a slip for a given purpose by pouring a little from a jug. In general, "heavy" slips are used for large, thick-walled ware. A "heavy" slip may contain about 82% alumina by weight, or about 53% by volume; whereas a "light" slip may contain about 67% alumina by weight, or about 34% by volume. The respective densities are about 2·56 and 2·00. (The density of alumina is 3·96).

Some difficulty may be experienced through the formation of a bubbly scum on the slip. It may be sufficient to skim this off, but sometimes it becomes necessary to add a large volume of water to the slip, to let the alumina settle, and to siphon off the excess water.

* Communication from the National Physical Laboratory, Teddington.

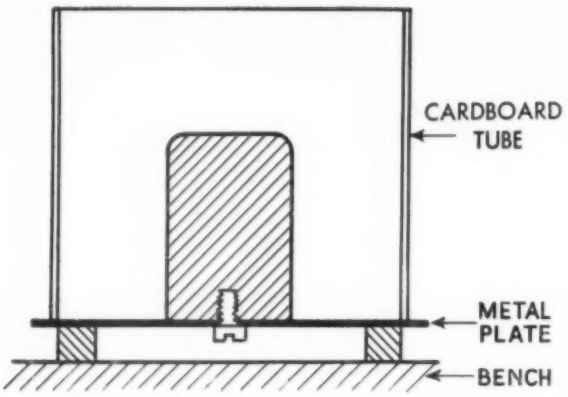


Fig. 1.—Preparing plaster mould for crucibles.

Vacuum treatment may be effective on a small scale, but is inconvenient on a larger scale. Heating the slip to about 60° C. before dilution is also useful.

In comparing the casting of a fine alumina slip with the casting of a clay slip, it should be realised that a clay slip normally contains "opening" material, the grains of which are much coarser than those of the clay. This is true even for a fine porcelain body, for impermeability after firing is a result of partial fusion of the body. In the case of alumina ware, however, impermeability after firing results from a closing of the voids by grain growth, and for a given firing schedule, voids below a particular size fail to close. Such voids may be initially present in a coarse aggregate, or may be formed by the shrinkage of fine material surrounding a relatively large grain. Hence, to achieve impermeability *without using an extremely high firing temperature*, the casting must be composed entirely of very fine grains. In practice there should be little or no material coarser than 15 μ. During firing, the voids tend to close progressively, the smaller ones first, but if the maximum temperature be long maintained, voids above a certain size (increasing with a rise in maximum temperature) are extremely persistent.

From the foregoing, it may be thought that the finer the slip, the better the results, provided that the range of grain sizes be sufficient for reasonably close packing. There is, however, an optimum mean size for the grains, depending on a number of factors. When a slip is slightly coarse, an inconveniently high firing temperature is needed to make the ware impermeable. When, however, a slip is too fine, and even though the grain sizes may be properly distributed, the cast body has a lower bulk density than that associated with a normal slip, and a low bulk density in the unfired ware corresponds with a relatively high shrinkage on firing to form an impermeable material. Moreover, casting is inconveniently slow with a very fine slip. It is probable that a slip such that half of its particles are finer than 1½ to 2 μ is fine enough for most purposes, and is usually too fine. The most useful slips for impermeable ware have, therefore, a mean particle size, as defined above, of from 1½ to 4 μ or thereabouts.

Slip-Casting Crucibles and Making Plaster Moulds.

Let us now consider the casting of a small crucible having a diameter of an inch or two. We may assume that the crucible is cylindrical, since this shape is often needed for use in a high-frequency induction furnace. The pattern may be conveniently made of brass and must be of the shape of the outside of the required crucible. Linear firing shrinkage may be about 15%.

The pattern should be finished with a high polish, and should be accurate. It is essential that there should be no taper "the wrong way." A flat circular metal plate having a diameter somewhat larger than that required for the mould should be screwed to the top of the pattern. This assembly is supported upside down, and a cardboard tube is placed round the pattern as in Fig. 1. Plaster is then poured round the pattern, bubbles being removed if necessary by tapping the tube, and by stroking the pattern with a thin stick. To prevent the plaster from leaking at the bottom circumference of the cardboard, a little plaster should be run round the outside and allowed to set before making the mould; this may not be necessary in the case of a very small mould. The pattern should be twisted out slowly from the set mould, as too much haste may cause damage owing to the strong suction. If for any reason the mould container is made of rigid material instead of cardboard, there must be some means of slightly expanding the container before the plaster is hard. Failing this precaution, the pattern will be gripped by the plaster, which expands a little on setting. Thus, a sheet metal cylindrical container should have a longitudinal joint which can be undone. If a rectangular wooden box be used, the sides should be held by screws which can be withdrawn. The thickness of plaster surrounding the pattern may be varied within wide limits. Moulds should be dried at a temperature not exceeding 60° C.

The removal of the pattern from a plaster mould can be facilitated by lubricating the pattern with a weak solution of soft soap, but moulds made from a well finished metal pattern tend to be of better quality when no lubricant is used.

Owing to the absence of coarse particles from the alumina slip, a freshly formed drain-casting offers much resistance to the flow of water through it, so that parts very close to the mould dry quickly, while the rest dries very slowly. The drier part should shrink away from the mould, but the shrinkage is small, and the casting tends to stick to the mould owing to the keying action of the pores in the plaster. If the inner parts of the casting were drying at a speed comparable with that of the outer parts, the inner parts would shrink, and would also be strong enough to help in pulling the whole casting away from the mould. When, however, the inner parts are comparatively wet, their lack of strength may result in the whole casting sticking to the mould, and the drying shrinkage may take the form of a reduction in the thickness rather than in the circumference of the casting. This phenomenon can usually be prevented by drying the inside of the casting as quickly as possible with a hot air blower of the kind used by hairdressers. (This may not be necessary when using a very fine slip because the casting is stronger than in the previous case, and its shrinkage is also higher. Both these factors help the casting to pull itself from the mould). In some cases difficulty is experienced in spite of the use of a hot air blower, and it is then worth while to lubricate the mould with oil before casting. The mould should be filled quickly with the oil, which should then be quickly drained out. The small amount of oil remaining will disappear into the plaster, after which the mould may be used. The rate of casting will be greatly reduced by the use of oil. Special oils are sold for this purpose, but

other oils ranging from olive oil to a penetrating oil have been found effective.

It is sometimes necessary to make a crucible through the wall or bottom of which passes a tube with the inner end closed. The tube may be intended to contain a thermocouple or a heating coil, or may be used for optical pyrometry. To make such an article, the crucible and the tube should be slip-cast separately, and it helps to narrow the tube uniformly towards the closed end. The unfired, but dried, crucible may be drilled with care, and the tube may be joined to it with alumina slip applied with a brush. Owing to the small drying shrinkage, this process does not produce serious strain at the joint. Sometimes the dimensions of the parts may hamper manipulation. For example, it is difficult to paint slip on the inside of the joint between a tube and the bottom of a long narrow crucible. In such cases the crucible and tube may be fired to about 1,200° before drilling the former, and fitting the latter. To effect the joining, the parts should be wetted, and a little slip painted round the open end of the tube. On pushing the tube through the hole in the crucible a tight joint is easily made when the tube is slightly tapered. When joining fired parts it is *essential* that the joint be a good fit apart from the use of slip. Otherwise, the differential shrinkages at the joint will cause cracks. It is also advisable to make the tubes by the same process as that used for the crucibles, normally slip-casting.

It will have been noticed that holes in the wall or base of a crucible are usually made by drilling. A hole may also be made in the bottom of a crucible by using an oiled metal core which is withdrawn during casting at the earliest practicable time, so as to avoid shrinkage cracks. The use of a core would not be worth while for the production of only a few crucibles.

Extrusion of Alumina

Extrusion of alumina is more difficult than that of clay because of insufficient plasticity. It is usual to improve the plasticity by the use of gum tragacanth, starch paste, rubber solution, or a dope of the cellulose acetate type. These substances are viscous rather than plastic, and the pastes made from them have so low a yield point that the extruded article tends to deform. Rubber solution and dope, owing to their volatile constituents set quickly at the surface, and minimise the tendency to deform after extrusion. Mixing of the powder with the latter substances, is correspondingly difficult, and it is often advantageous to leave material overnight in the extrusion machine, evaporation being checked by sealing the die with plasticine. This, of course, wastes time, and plasticisers with very volatile constituents are little used outside the Laboratory. All plasticisers should be used as sparingly as possible in order to avoid porosity in the finished ware.

Sealing the end of a tube which has been extruded with a cellulose acetate dope is not easily carried out by softening the tube with solvent and gradually closing in the end, for the softening process tends to go too far, and to produce a body which behaves like a mixture of sand and water. The dried tube can be sealed, however, by closing the end with some of the soft body used for extrusion. A little solvent may then be applied to the joint, and the surfaces may be worked together with the aid of a suitable tool inserted in the tube. There is a tendency for the closed end of even commercially produced tubes to be slightly pervious to gas. In some cases it may be convenient to make a closed tube by slip-casting, and thus ensure a sound end.

Screw Threads on Tubes

Externally threaded furnace tubes may be needed as supports for platinum, molybdenum, or tungsten windings. For this purpose the cast tubes are fired to 1,200° C., and the threads are cut on a lathe using a hacksaw blade as a tool. The tube is supported at both ends, and the blade is pivoted in a horizontal position so as to rest on the top of the tube, the end of the blade being suitably weighted. The lathe is run slowly, and a thread is cut to a depth depending on the weight attached to the blade ; the teeth wear quickly, so that the thread becomes shallower as the work progresses. This can be remedied by repeating parts of the cutting, and by changing the blade if necessary. The reason for using a pivoted blade instead of a fixed tool is that the former follows any variations from circularity. It would, of course, be feasible to use rollers to prevent the blade from cutting below a predetermined depth, and to repeat the cutting until this depth has been reached at all points. This has not been thought worth while for laboratory purposes, because small variations in the depth of the thread do not influence the security of the winding.

Lined Alumina Crucibles

At very high temperatures, in a reducing atmosphere, alumina crucibles may be reduced to some extent by certain metals. Thoria is usually more resistant to reduction, and a thoria slip may be sprayed thinly on the inside of an alumina crucible which has been fired to, say, 1,200° C. The treated crucible is then re-fired to 1,500° C., or more, according to the use to which it will be put. Owing to the cleanliness of the metal under the usual conditions of a high-frequency furnace a thin porous layer of thoria is sufficient to prevent contact between the metal and the alumina. It is essential that spraying with thoria should be carried out under such conditions that no thoria can be breathed either by the operator or by others, both during the spraying and afterwards. Before handling thoria it is advisable to consult the Medical Research Council with regard to the precautions which should be taken against dangers to health.

Drying and Firing

The drying shrinkage of alumina ware is very low, and difficulties rarely arise during drying. Completely dry ware is, however, weak and brittle, and it is often convenient to place the ware in the furnace while still slightly damp, in which state it may be more safely handled.

Owing to the high temperature needed to produce dense ware, firing is a matter of some difficulty. For small articles, a gas-furnace fired with an " injector " burner is convenient when high-pressure air is available. A description of such a furnace appeared in *Trans. Brit. Ceramic Soc.*, Vol. 39, p. 1, whilst the " injector " burner is described on pp. 353/4 of Vol. 37. As the burner is capable of producing very rapid changes of temperature, fine control of the gas and air valves is necessary. The gas pressure should be governed, and a large gauge should permit easy reading of the air pressure at the burner. In compliance with factory regulations a non-return valve must be fitted on the gas supply not far from the burner, the governor being between this valve and the burner. With reasonable attention, consisting mainly of painting

the inside of the furnace with alumina slip, so as to close cracks, the furnace mentioned should have a long life. Furnaces may be improvised, however, and built quickly with standard bricks. The furnace may be square inside in plan, and if super-refractory bricks are not available, a water-bound alumina lining may be moulded in position and fired slowly. Such a lining may consist of four parts of fused alumina, to pass a sieve of about 90 meshes per inch, mixed with one part of very fine alumina to act as a bond. After the first heat to, say, 1,600° C., the cracks in the lining caused by shrinkage should be patched, and the furnace heated again to, say, 1,700° C. By repeatedly patching and refiring at progressively higher temperatures a sound lining may be obtained. The burner brick may be similarly moulded, fired in position, and patched as found necessary. These methods are tedious, and lead to a furnace of shorter life than that described above, but they have the advantage of not necessitating the prior use at very high temperatures of a furnace which, for convenience, should be larger than the one to be built, in order to make the more refractory parts for the latter. The ware to be fired in an "injector" furnace must be protected from the flame, a cylindrical crucible being usually convenient for this purpose. This crucible may be made, as described later, from the mixture of fused alumina and finer material mentioned above, and should be fired in another furnace to 1,500° C. or more. So as not to waste furnace space when a number of small articles are to be fired, it is usually desirable to bury the articles loosely in alumina powder placed in the crucible, which itself must be provided with a lid to prevent powder from being blown about during the intermediate stages of the burn. A firing schedule which is often suitable for small articles involves the maintenance of 1,800° C. for 1 hour. After such treatment it is difficult to remove the ware from the mass of sintered powder in which it is embedded; the use of a great deal of water will be found to help considerably. Alumina tools made from damaged ware may be used for the operation. Steel tools may be used with caution for the early stages, but they mark the ware if contact occurs.

The firing of large articles involves heavy capital expenditure from which it is difficult to see any immediate prospect of escape. A furnace which has given good service for such work has been described in the *Bulletin of the British Refractories Research Association*, Sept., 1941, p. 1. A difficulty with the burners, discussed on page 7 of this *Bulletin*, has been overcome. The latest burners are 6 in. high, and the centre of the gas aperture is $1\frac{1}{2}$ in. above the bottom. The greater part of the aperture has a diameter of $\frac{3}{4}$ in., but the part where the gas passes out has a diameter of $\frac{5}{8}$ in., and is inclined upwards at 45°. The gas emerges from this passage near the top of the brick. A slight seepage of gas due to the porosity of the burner bricks has been rendered negligible by applying aluminium paint to the outside of the brickwork in the neighbourhood of the burners. The furnace has given satisfactory service at 1,750° C. By the substitution of more refractory bricks in the hotter parts, a working temperature of 1,800° C. may be used, but it will be understood that aluminous bricks containing a proportion of silica cannot have a high margin of safety at this temperature. Pure alumina bricks would be sufficiently refractory, but would be liable to spall.

If a similar furnace be built of aluminous firebricks of good quality, alumina tubes being used in the recuperator, the cost is greatly reduced, and such a furnace can give excellent service for temperatures up to 1,500° C. Many refractories fired at this temperature may be used at much higher temperatures.

MISCELLANEOUS REFRACTORIES

Particularly for High Frequency Electric Furnaces

For laboratory high-frequency metal melting, the outer vessel may be made by slip-casting a mixture of 60 parts by weight of silicon carbide (all grain sizes passing through a sieve of 40 meshes per inch) and 40 parts of refractory china clay. The silicon carbide should be "for refractory purposes," as material intended as an abrasive may have too high an iron content. The slip is made up with water and a deflocculant. A mixture of sodium carbonate and sodium silicate may be used for this purpose. The proportions should be such that about $\frac{1}{16}$% of the weight of dry material is equal to the weight of sodium oxide contained in the added carbonate, and the same amount of sodium oxide should be present in the added silicate. Trials may be necessary to determine the best proportions, but these figures will serve as a guide; an excess of deflocculant causes coagulation. It is important that the slip should not be too thin, or the silicon carbide will settle, and it should also be remembered that clay slips improve with age. The silicon carbide slip specified above casts easily. The ware should be fired to cone 14, and the linear shrinkage in terms of the pattern should be about 4%. Too high a firing temperature will oxidise the silicon carbide and produce a bubbly skin of silica. Silicon carbide ware made as described above has high strength and is very resistant to thermal shock. For high temperature melting, the inner crucible will usually be of impervious alumina, the space between the two vessels being packed with alumina powder. The inner crucible is usually required with thin walls and on small sizes the wall thickness may be about 1/40 of the diameter, while for large sizes a ratio of about 1/20 is more suitable. Warping during firing is difficult to avoid when the walls are too thin.

It is sometimes convenient to use a pervious alumina crucible made by tamping as described later. For some work slip-cast crucibles consisting mainly of china clay may be used. An appreciable quantity of silicon may pass from the crucible to the melt if the operating temperature be too high. A suitable mixture for a clay crucible is 75 parts refractory china clay and 25 parts calcined alumina; a deflocculant should be used. The linear shrinkage is about 14% for a burn to cone 20. Less refractory crucibles may be made from 60 parts refractory china clay and 40 parts of calcined sillimanite (all grain sizes passing through a sieve of 50 meshes per inch). In this case the linear shrinkage is about 12% for a burn to cone 20.

It has been mentioned that for some purposes tamped crucibles may be used. Wall thicknesses are rarely less than 5 mm. for crucibles of small bore, or 1 cm. for a bore of 10 cms. Tamped alumina crucibles may be made from 4 parts fused alumina to pass through a sieve of 90 meshes to the inch, and 1 part of finely ground alumina. When fired to cone 20 the linear shrinkage is about 2%, and when fired at 1,800° C. for 1 hour, the shrinkage is about 4%. If the grain size of the fused alumina is uniform, the products may be cut with a hacksaw, but if the grains of fused alumina embrace a wide range of sizes, the products will be very hard. The two materials may be conveniently mixed in a stone jar

run on rubber- or rope-covered rollers at "ball-mill speed." A wooden rod should be wedged diagonally in the jar so as to produce an endwise flow of material. When mixing has been achieved the rod can be removed, and water added. Rotation of the jar will soon produce a uniform distribution of water, and the material will form into balls which should have a diameter of about 5 mm. (The addition of a water-soluble adhesive in order to strengthen the body increases the size of ball which gives the best results). The damper the material the larger are the balls. Another test of dampness can be made with the hands: the mixture should not soil the hands when rubbed gently, but should cohere when squeezed between the finger and thumb. The amount of water needed depends a little on the method of tamping. For hand tamping a little more may be used than that suitable for tamping with a pneumatic tool. It is sometimes advisable to add starch paste to the mixture in order to facilitate handling of the "green" (i.e., unfired) ware. Ammonium alginate may be used for many refractories, but it tends to be decomposed by alumina.

Three kinds of apparatus are in use at the National Physical Laboratory for making tamped crucibles. The first type is very simple, but is suitable for small crucibles only. Fig. 2 shows an axial section of the two brass parts in position for filling. Material is placed in the mould in *small* quantities at a time, and is thoroughly tamped with a wooden tool shaped like a blunt screwdriver. The mould is slightly overfilled, and the excess material is levelled off with a palette knife. A disc which can slide easily in the outer cylinder is placed on the levelled material, and the whole arrangement is inverted and placed on a vertical cylinder of diameter a little less than that of the disc, and of length sufficient to allow the outer cylinder to be pushed down and leave the disc, crucible, and core supported on the solid cylinder. A piece of paper is then wrapped round the crucible, which is gently held in the left hand, while the core is twisted out with the right hand. (A slight taper on the core is a great help, but a cylindrical core can be removed with care). At this stage the crucible may be placed on a suitable powder for firing, and the paper may be removed, or left to be burnt away. It may be mentioned that when placing such a crucible on powder for firing, the central parts of the powder should be hollowed out so that the weight of the crucible is mainly supported by the powder underneath the walls of the crucible. Neglect of this precaution sometimes causes fracture of the base of a crucible when the temporary bond has been destroyed during firing.

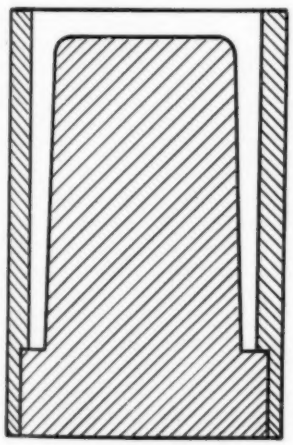


Fig. 2.—Apparatus for making tamped crucibles in small sizes.

For larger crucibles two other kinds of apparatus have given good service. The first type is accurate, and has a long life, but is somewhat expensive. The second type is cheaper, and not quite so accurate. It is very useful, however, when the total output is likely to be small. Fig. 3 shows the more accurate type with the core partly withdrawn. The outer block, of light alloy, is in three equal parts which are clamped with brass fingerbolts on to a brass ring through which the light alloy core is screwed. The mating surfaces of the brass ring are at 45° to the vertical, there being a clearance between the vertical surface of the ring and the adjacent part of the outer block.

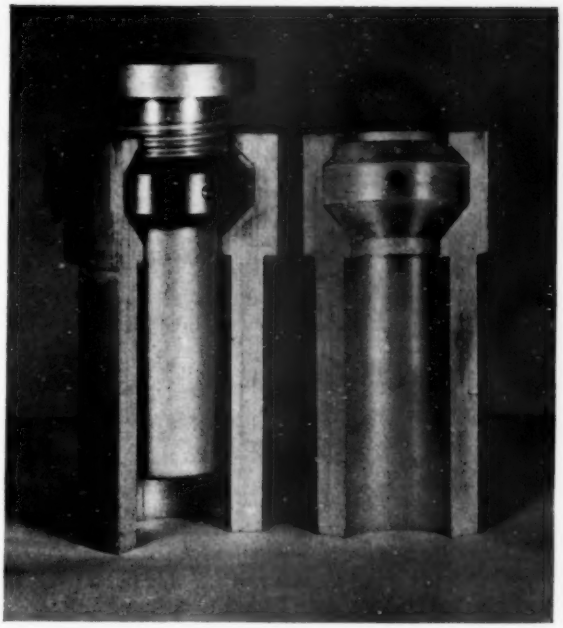


Fig. 3.—Apparatus for making tamped crucibles in larger sizes.

To make a crucible, the apparatus is assembled and placed upside down. (The finger bolts should not be screwed very tightly, or the brass ring will distort and prevent the easy unscrewing of the core). The mould is lined with an overlapping piece of paper long enough to act as a funnel at its upper end. Material is then tamped into the mould in the usual way. If a machine be used for tamping, a thin flat rubber ring should be dropped into the mould before the filling begins. This will stop what will later be the top edge of the crucible from sticking to the metal mould. The rubber ring can, of course, easily be peeled from the crucible, but with hand tamping this precaution is usually unnecessary. After filling the mould with a slight excess of material, the projecting paper is cut off with a razor, and the material is levelled off with a palette knife. The mould is then placed right side up on a light alloy slab, and the core is unscrewed and removed. (The core is usually slightly tapered. If a cylindrical core is necessary the strong suction during removal is usually enough to break the crucible. This can be prevented by drilling the core axially, and placing a thin piece of paper over the end of the hole before starting to fill the mould). The outer block is next removed in sections, leaving the crucible standing on the slab. The paper covering may be peeled off, or left to burn in the furnace. It will have been noted

that the fingerbolts are assumed to be sufficient to hold together properly the three sections of the outer block. It may be desirable, however, to slip a clamping ring over the end of the mould remote from the brass ring so as to prevent the tamping pressure from forcing the three sections slightly apart. In large sizes the apparatus described above is inconveniently heavy, and some saving of weight may be effected by using a hollow core. When crucibles shorter than the standard are needed, part of the mould may be blanked off with plaster of paris.

The disadvantage of the apparatus just described is the time needed to make it. The following alternative is satisfactory in most cases in which a large output is not needed. The outer part of the mould consists of a brass tube. Two parallel rectangular bars, separated by a little more than the width of a saw blade, are soldered along the length of the tube on the outside. The blade is removed, and cheese-head screws are fitted at intervals to pass through clearance holes in one bar and into threaded holes in the other. The screws are removed, and the tube is sawn longitudinally between the rectangular bars. After cutting, the tube tends to spring open, but can be closed again by means of the screws. A circular base-plate, having a diameter larger than that of the tube, is turned so that a shallow cylinder projects upwards. This is a sliding fit in the bottom of the tube when the latter has been closed by the clamping screws. Within the tube, thus held, a core must be fixed, the space between core and tube corresponding with the inverted crucible required. A small core may be made of solid metal, whilst a large core is made from a tube closed by a thick disc at each end. In either case, the core is held in position by a central screw passing upwards through the base-plate, and countersunk in the latter. The crucible is tamped in the usual way, using a paper lining for the tube. After tamping and levelling, the whole assembly is placed on another plate so that the crucible is the right way up. The screw holding the original base-plate (now inverted at the top of the crucible) to the core is removed, followed by the base plate, which is easily released from the tube by gentle upward tapping round the projecting edge of the plate. The crucible, enclosed in the outer tube, is now right side up. A metal plate similar to the original base plate, but with a central aperture through which the core can just pass freely, is fitted to the outer tube, the projecting annulus serving to hold the material of the pot in position during the extraction of the core. A stout tube is placed on end on the plate just mentioned, and a bar with a central hold is placed over the upper end of the tube. A long threaded rod is passed through this hole, and its lower end is screwed into the blind tapped hole in the core. By screwing a nut on to the top of the rod, the core is forced out of the crucible. This can usually be done without damage to the base of the crucible. In case of difficulty it may be necessary to twist the core before attempting its removal. After removal of the core, the screws which clamp the split tube surrounding the crucible are slackened, and this tube is removed. The paper lining of the tube remains on the crucible, and can be peeled off.

Mention has been made of tamping by means of a pneumatic hammer. The use of a machine saves time, and should facilitate the attainment of a uniformly high density. For small articles, however, the machines tend to be too powerful. It is, therefore, often advisable to use a low air pressure (e.g., 40 lb./sq. in. instead of 150 lb./sq. in.), and to arrange that the tamping surface is of adequate area. An annular tool may often be used for tamping a crucible, but for hand tamping, a tool should be wedge shaped, or have serrations or sinuosities, in order to avoid lamination. The outside of the tool should be bevelled inwards so as not to tear the paper lining of the outer tube. When using a machine, the shape of the tool is less important, and a plane tamping surface may be quite satisfactory.

In designing moulds for tamped articles of various shapes, attention must be given to the method of freeing the article. In general, a mould surface should be sheared from the tamped article, which should be supported so as to avoid tension and, therefore, bending. Wooden moulds may be soaked in molten paraffin wax to make them waterproof and to reduce the tendency of the tamped article to stick. In many cases a tamped article may be separated from its mould by tapping so as slightly to compress the article. Thus, a cylindrical block of considerable length may be tamped in a metal tube. On tapping the tube, enough clearance for its careful removal by hand may not be found difficult. Longer tubes may be slit, and held together during tamping as previously described.

Reference has been made above both to the necessity for not imposing a tension on a tamped article, and to adherence of the article to a mould surface, which produces tension if the surface of the mould be moved away from that of the article. The insertion of paper, plastic sheet, or thin fabric between the surfaces is one method of preventing adherence. When removing the flexible sheet, however, undue tension may easily be imposed on the article. Such tension is minimised by doubling back the sheet, and pulling it away tangentially. Inextensible sheets cannot, of course, be applied to surfaces of any shape, and adherence is often reduced by dusting the surfaces with a suitable powder (usually of the same material as that of the article), or by the application of a liquid lubricant. The choice of the best method is determined by experience or by trial.

For high-frequency melting, supports and other articles may be required which need not be as refractory as the crucibles. A useful body for many purposes consists by weight of 4 parts of sillimanite, 1 part of refractory china clay, and 1 part of dried alumina slip. The sillimanite may be bought as a crushed product which has passed through a sieve of either 10 or 50 meshes to the inch, the user's choice depending on the dimensions of the article to be made. For tamped material, using the coarser sillimanite, the linear shrinkage is about 1% for any firing temperature between 1,400° and 1,600° C. The material has very good thermal endurance, and for this reason is suitable for crucibles provided that the presence of silica may be tolerated.

A refractory article is, unfortunately, often needed urgently. For such things as furnace stoppers, the easiest thing to do is to machine the article from a porous heat-insulating brick. Dust can be avoided by wetting the brick. For other purposes something stronger may be needed, and it is often useful to have a stock of underfired machinable material. This can be cut to shape and re-fired. Ware of an awkward shape can be made in this way without making complicated patterns. An example has already been given of the production of threaded alumina tubes. The sillimanite-china clay-alumina mixture mentioned above, and con-

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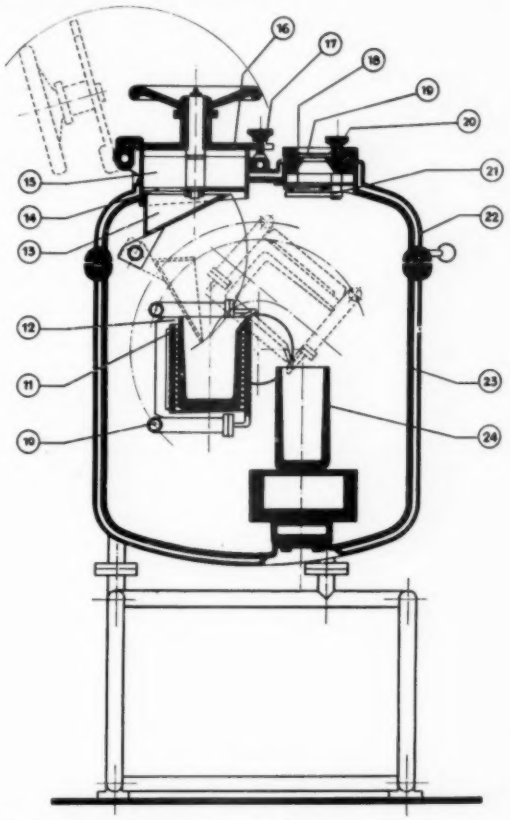
High-Vacuum Melting

Latest Swiss Developments

A SUITABLE high-vacuum plant enables melting to be carried out, under practically ideal conditions, of special steels, copper, alloys with readily oxidising constituents such as beryllium copper, alloys for permanent magnets, metals such as titanium, zirconium, manganese, chromium and their alloys. Sintering of molybdenum and tungsten can also be carried out in the same type of plant. A newly developed installation of this type by the Swiss firm Geraetebau-Anstalt Balzers, of Balzers, Liechtenstein, is shown by the photograph (Fig. 1).

The melting unit of the apparatus may be described as a simple tilting furnace with its accompanying mould, operating within a vacuum chamber, as will be seen from the sectional view (Fig. 2). The furnace or crucible, which in the case of the plant illustrated has a capacity of 22 lb. steel, is electrically heated by a high-frequency induction coil, and pouring is effected by tilting the crucible by means of an outside lever handle until the contents are poured into the mould. The greater portion of the constituents of a charge are loaded into the hopper 15 in the requisite order, a smaller portion being charged into the furnace and melted. When this stage is reached, the hopper is turned about the opening 14, and the measured quantities of material which it contains are

Fig. 1.—A general view of the plant.



10 Pivoted support for furnace.
11 Induction coil for ditto.
12 Crucible.
13 Scoop for depositing successive charges in crucible.
14 Rotating disc or bottom.
15 Hopper with six compartments.
16 Cover for hopper.
17 Locking nut.
18 Fixing for inspection window.
19 Outer window.
20 Handle for window wiper.
21 Wiper for inner window.
22 Outer casing of vacuum chamber.
23 Inner casing.
24 Ingot mould.

Fig. 2.—Section through vacuum chamber.

deposited on the tilting chute 13, from which latter it is charged into the crucible by tilting a lever. With this arrangement it is, therefore, not necessary for the crucible to be fully charged at the commencement of the melt, as it is readily possible for certain material to be added either at the conclusion of the melt when necessary, or at any point during the process.

The vacuum chamber 23 and the cover 22 are of stainless steel and they are both water-cooled. Two springs are provided to ensure easy opening and closing of the cover. For the control of melting and pouring, means are provided for observation by an inspection window under a protecting cover glass. In case of heavy vapour yield or splashing, the protective cover can be withdrawn for cleaning by turning the knob 20 in fitting 21.

With empty crucible and H.F. coil, the pumping time for the plant is about 5 minutes for 10^{-2} mm. Hg, or about 10 minutes for 10^{-4} mm. Hg, the pumping set (apart from instruments and fittings) consisting of a

diffusion pump having an evacuating speed of 500 litres per second at 10^{-4} mm. Hg, this pump being of the three-stage water-cooled type with oil regeneration and having an oil content of 250 cm.^{3} The vacuum pump is of the two-stage air-cooled rotary oil type, the speed at normal pressure being 25 m.^{3} per hour, and suitable for an ultimate pressure of 2×10^{-3} mm. Hg without air ballast. This pump is also provided with automatic oil regeneration, and a non-return device is incorporated which, in conjunction with the small oil content of 0·5 litre, prevents any flow-back of oil into the vacuum line in the event of any failure of the electric supply for the motor. This latter is of 1·2 h.p.

With regard to production of the plant, for melting steel, an interval of between 30 and 60 minutes is necessary between the closing and the final reopening of the vacuum chamber, the exact time being dependent upon such factors as the end vacuum required and the amount of gas yield, also whether it is a question of a simple melt or the manufacture of an alloy.

Large Order Completed in Record Time

British Insulated Callender's Cables, Ltd., have supplied 550 miles of bronze and cadmium-copper telegraph wire to Jamaica for restoration of the Island's hurricane-wrecked telecommunication systems.

It is of particular note that 100 miles of bronze wire contained in this order was required with the utmost urgency and was therefore produced and despatched by air only six days after the S O S call was received. The work had to be started more or less from scratch and included casting, hot rolling, wire drawing and inspection. However, with facilities for all this work in one factory and by both management and workers making a special effort—working many hours of overtime including a whole week-end—the goods were made ready for despatch in record-breaking time.

In detail, the complete order consisted of 400 miles of 40 lb. per mile bronze wire, 100 miles of 100 lb. per mile cadmium copper wire, and 50 miles of 70 lb. per mile cadmium copper wire.

Instrument Training Courses

As the complexity of industrial instruments increases, the necessity of providing users with an adequate explanation of the theory and practice of instrumentation becomes more apparent. George Kent, Ltd , of Luton have for many years made a practice of giving an extremely thorough training to individuals sent to the Works by user firms. Kent's have now begun a series of integrated courses for instrument mechanics and engineers from customers, to give this training on a more centralised basis.

The courses last for four or five weeks, depending on the requirements of the trainees, during which period whole-time instruction is given by a qualified training staff on the theory, operation and maintenance of a wide range of Kent instruments and control apparatus. A workshop and lecture room have been specially provided and equipped for training courses at the Luton Works, so that trainees get the full benefit of working and comparing notes together.

First results have been most encouraging, and there is now a greater demand for places on the courses than can be satisfied in the immediate future. Firms wishing to send trainees on these courses should address their enquiries to the Training Officer, Luton.

Northern Aluminium Co., Ltd., announce that from October 1st next, the address of their Head Office and London Area Office will be: Bush House, Aldwych, London, W.C.2; telephone: Temple Bar 8430; telegrams: Noraluco Estrand, London.

New Pyrometer Factory

Since the formation of the Industrial Pyrometer Co., Ltd., in 1946, very rapid progress has been made indeed and, in the short space of five years, it has grown from a small beginning into one of the principal pyrometer manufacturers in the country. Success has been largely due to progressive design in conjunction with standardisation of parts and a very wide range of indicating, recording and controlling pyrometers is now being produced for the metallurgical, chemical, rubber and other processing industries. In order to provide adequate production facilities to satisfy the increasing demand, the company will shortly be moving to a new 5,000 sq. ft. factory in Gooch Street, Birmingham, 5.

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taining the finer grade of sillimanite, machines nicely after a burn to 1,200° C.

When the means of firing at high temperatures are not available, a mixture by weight of 4 parts of sillimanite (to pass through a sieve of 10 meshes per inch) and 1 part of *ciment fondu* may be mixed with water, allowed to set, and fired slowly to 600° C., after which it may be used at temperatures up to 1,650° C. The substitution of fused alumina for sillimanite produces a material with a squatting point exceeding cone 38, but the material expands enormously at 1,500° C. as a result of the formation of crystals of mullite ($3Al_2O_3$, $2SiO_2$), and for this reason the mixture cannot be recommended.

Conclusion

Information has been given which may be of practical help to experimenters concerned with high temperatures, and particularly to users of high-frequency electric furnaces. Some of the operations described cannot easily be carried out successfully without considerable practice, after which the operator may be at a loss to know in what way he has altered his technique. This is a common experience, and should not be interpreted as an indication of unduly limited powers of observation.

Emphasis has been placed on alumina as a refractory because, for temperatures of 1,500°–1,800° C., it is the most generally useful material for a wide variety of purposes. Moreover, the methods of handling other pure oxides have much in common with those described for alumina.

Acknowledgment

The above Notes have been prepared as part of the research programme of the National Physical Laboratory and are published by permission of the Director of the Laboratory.